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Aeronautical Engineering REVIEW

August, 1956

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Aeronautical Engineering REVIEW

Vol. 15—No. 8 August, 1956

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Cover—The giant Douglas C-133A cargo plane, which made its first flight on April 23, is now in production for the Air Force at Long Beach, Calif. The first planes off the assembly line will go to the Military Air Transport Service. In test flights, the company said, the long-range military transport has lifted its design gross weight of 255,000 lbs. Powered by four turboprops, the C-133A has a cargo capacity of more than 100,000 lbs. It carries twice the pay load of the C-124 and almost seven times as much as the C-54.

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PANEL INSTRUMENTS

IAS News

A Record of People and Events of Interest to Institute Members

Tex Johnston Wins Chanute Award

Boeing's Chief of Flight Test Honored by IAS During Summer Meeting in Los Angeles

THE OCTAVE CHANUTE AWARD for 1956 was presented to A. M. "Tex" Johnston, Chief of Flight Test, Boeing Airplane Company, during the IAS National Summer Meeting in Los Angeles. The ceremony took place on the evening of June 20 at a dinner in the Biltmore Hotel.

More than 1,000 members and guests saw Edward R. Sharp, President of the Institute, make the presentation to the 41-year-old test pilot who has taken eleven different types of airplanes off the ground for their first flights.

Another guest of honor at the dinner was Theodore von Kármán, Professor Emeritus of California Institute of Technology. Coming a month after his 75th birthday, the affair had been planned as a tribute to the noted aerodynamicist.

The Chanute Award, consisting of a certificate and an honorarium of $200, is given annually by the Institute for "a notable contribution made by a pilot to the aeronautical sciences." It was established in 1939 to honor the memory of Octave Chanute, the American pioneer in experiments with gliders, who died in 1910.

In presenting the certificate, Dr. Sharp said Mr. Johnston had been selected by the Award Committee for his outstanding flight-test work over a period of years—not for any single achievement. He read a citation commending the experimental pilot for "combining the practical with the scientific approach in the initial flight testing and evaluation of high-performance jet aircraft and engines."

Mr. Johnston, who used to do aerobatics in a Ford Trimotor, has been a test pilot for nearly 14 years. He says he has flown more than 60 types of airplanes, ranging from World War II fighters to the huge Boeing 707 jet transport. He has logged 12,600 hours in the air, including 2,600 hours flying jets.

A native of Emporia, Kan., Mr. Johnston took flying lessons after graduating from high school and eventually joined a flying circus. Later, he studied aeronautical engineering at Kansas State College, working part time as a flight instructor.

His first taste of life as a test pilot came when he joined Bell Aircraft Corporation in 1942, after a term as a civilian flight instructor and ferry pilot for the Air Force. Some of the (then) experimental planes that he flew were the P-63, XP-77, TP-39, L-39, X-1, and the P-59, America's first jet-powered fighter.

In 1943 Mr. Johnston flight-tested America's first jet engine, the I-16, for General Electric Company and the Air Materiel Command.

In 1946, flying a modified P-39, he won the Thompson Trophy Race by setting a closed-course record of 376.4 m.p.h.

In 1949, following a period of development work on Bell helicopters, Mr. Johnston joined Boeing Airplane Company as a test pilot for the B-47 jet bomber. He conducted all the high-speed and stall tests on the B-47.

Two years later, he took charge of flight testing the giant B-52 jet bomber and was the pilot on its maiden flight.

In October, 1953, Mr. Johnston was named Chief of Flight Test, a position in which he directs the work of 600 persons and the operation of the $5,000,000 Flight Test Center at Boeing's main plant in Seattle. On July 15, 1954, he took the 707 jet tanker-transport prototype off the runway at Renton, Wash., on its initial flight. Despite his administrative duties, the Chief still spends a good deal of time flying the 707 and the B-52.

Mr. Johnston lives on Lake Washington, in Bellevue, Wash., about 15 miles from the plant.

The winner of the Chanute Award last year was Major Gen. Albert Boyd, USAF, who was then Commander of Wright Air Development Center at Wright-Patterson AFB, Dayton, Ohio.

A. M. "Tex" Johnston in the cockpit of the Boeing 707.

American Helicopter Society's Twelfth Annual Forum in Washington Sets Record for Attendance

With more than 600 registrations for the technical sessions and 850 persons present at the Honors Night Dinner, the Twelfth Annual National Forum of the American Helicopter Society was the largest meeting conducted by the organization to date. The Forum was held May 2–5 in the Sheraton Park Hotel, Washington, D.C.

Rear Admiral Lawrence B. Richardson, USN (Ret.), FIAS, addressed the Honors Night audience on "The Value of Technical Societies to Industry." He is Senior Vice-President for Engineering, General Dynamics Corporation. At a luncheon the following day, Major Gen. Hamilton H. Howze, USA, spoke on "The Army's Stake in the Helicopter."

At the Honors Night Dinner, the Dr. Alexander Klemin Award for 1956 was presented to Charles H. Zimmerman, AFIAS, Assistant Chief of the Stability Research Division, Langley Aeronautical Laboratory, National Advisory Committee for Aeronautics.

Established in 1951 by Frank N. Piasecki, FIAS, the award is given annually for "notable achievement in the advancement of rotary-wing aeronautics." Honoring Mr. Zimmerman for his pioneering research on the "flying platform," the plaque was accompanied by the following citation:

"For outstanding initiative and the highest type of creative imagination and engineering design. In 1947 Mr. Zimmerman conceived the idea of a rotor-powered air-borne platform capable of lifting a man and being controlled in direction by the simple principle of shifting the weight of the man's body. He reduced this idea to practice by constructing, as a private venture, a prototype deriving its thrust from an air jet. Having demonstrated the basic principle, he then proceeded to show that a rotor-sustained platform could equally well be controlled by the same means.

L. B. Richardson, FIAS, a Past-President of the Institute, speaking at the Honors Night Dinner of the American Helicopter Society in Washington.

"This idea, astonishing in its brilliance and simplicity, is the basis of several successful projects which will provide the Services with direct-lift vehicles of unparalleled simplicity capable of being used to a maximum effectiveness by personnel with minimum training. Mr. Zimmerman's originality of thought and resourcefulness in execution have thus resulted in a major contribution to the progress of direct-lift aircraft."

Lieutenant General James M. Gavin, USA, Chief of Army Research and Development, accepted the Capt. William J. Kossler Award on behalf of all the military services and the helicopter industry. The award was given this year to "those organizations that participated in the numerous rescues during the diasastrous floods in the United States and Mexico during the year 1955: the U.S. Army, Navy, Marine Corps, Air Force, Coast Guard, and the Helicopter Industry of the United States."

The Kossler Award is given for "greatest achievement in practical application or operation of rotary-wing aircraft, the value of which has been demonstrated in actual service during the preceding year." During the floods in New England, Mexico, and California, thousands of persons were removed from precarious and inaccessible places by helicopters.

Honorary Fellowships in the American Helicopter Society were presented to Jackson E. Beighle, Sales Manager of Sikorsky Aircraft Division, United Aircraft Corporation, and Friedrich L. von Doblhoff, Helicopter Chief Engineer, McDonnell Aircraft Corporation.

Seventeen papers and a film were presented in the technical sessions, which ran for 2 days. Industrial displays were set up in the hotel's Exhibition Hall. The last day was devoted to a display and demonstration of military and commercial helicopters at Anacostia Naval Air Station.

Charles M. Seibel, MIAS, Chief Engineer of the Helicopter Division of Cessna Aircraft Company, was elected President of the American Helicopter Society, succeeding Brig. Gen. William B. Bunker, USA. Rene H. Miller, MIAS, of the Massachusetts Institute of Technology faculty, was elected Secretary. Colonel Robert R. Williams USA, MIAS, of the Army Aviation Service Test Board, was named Treasurer.

Regional Vice-Presidents elected were Bruce A. Goodale, Comdr. William G.

Brig. Gen. William B. Bunker, USA, MIAS, President of the American Helicopter Society, presents the Dr. Alexander Klemin Award to Charles H. Zimmerman, AFIAS, Head of the Dynamic Stability Branch at Langley Aeronautical Laboratory, NACA, for his research on "flying platforms." At right is J. P. W. Vest, Awards Chairman.

Knapp, USN, Marvin D. Marks, Herbert F. Moseley, H. Stever Tremper, and Robert H. Wheelock.

Speaking at the Honors Night Dinner, Mr. Richardson remarked that there are now more than 100 national and international societies in engineering and scientific fields in North America. New societies are formed almost every year, and seldom does one expire.

"Whatever duplication of effort there may be," he said, "is justified by the fact that bigness, in itself, does not engender efficiency or quality, especially where there exists the great diversity of knowledge and techniques required by today's engineering profession as a whole.

"Furthermore, there is some advantage in having a number of societies (including some of the older ones which originally had no aeronautical connection) holding technical meetings and discussions in the broad field of aviation. Each meeting offers opportunities for interchange of information and for young engineers and scientists to gain recognition and develop professional leadership.

"The element of competition, which undeniably has developed among the societies, has its advantages also—if not overemphasized—in that competition tends to enhance the quality of the meetings, the papers accepted for presentation, and the discussion. In the matter of spontaneous and informal discussion from the floor at technical meetings, the American societies are noticeably weak, particularly in comparison with their British and Canadian counterparts."

Mr. Richardson pointed out that the technical societies can perform a valuable service in connection with the *esprit de corps*, the ambition, and the general work satisfaction of engineering employees.

"I think that mature professional engineers are content to work in the large engineering departments which are now so necessary," he said. "However, some young engineers employed in the major companies may feel that they are individually helpless and disregarded, in spite of the best efforts of engineering management to provide training and broadening assignments. To these discontented engineers the technical society offers tangible help through its local section activities, including opportunity for self-improvement, expression, and recognition of initiative.

"The societies and their local sections must scrupulously avoid any action which smacks of negotiations or of attempts to serve the selfish interests of groups of engineers against employers or against other employees. However, the technical society does help its members to attain greater professional competence and the wider opportunities which this brings. The society builds up the entire profession in knowledge, skill, and status. In the long run, the individual stands to profit more from this effort than from any sort of pressure-group action."

Mr. Richardson urged industry to support more engineering scholarships. He also discussed the work of the Engineers Joint Council.

Donald W. Douglas

Donald W. Douglas Wins Elmer A. Sperry Award

Donald W. Douglas, President of Douglas Aircraft Company, Inc., has been chosen to receive the 1956 Elmer A. Sperry Award "in recognition of his distinguished engineering contribution which has advanced the art of transportation through the development and production of the 'DC' series of airplanes."

The selection of Mr. Douglas, who is an Honorary Fellow and a Benefactor of the IAS, was announced by Robert B. Lea, AMIAS, Chairman of the Elmer A. Sperry Board of Award. The annual award is sponsored by four societies: the American Institute of Electrical Engineers, The American Society of Mechanical Engineers, The Society of Automotive Engineers, and The Society of Naval Architects and Marine Engineers.

The bronze medal, accompanied by a certificate and honorarium, will be presented during the National Aeronautic Meeting of the Society of Automotive Engineers in Los Angeles in October.

The Sperry Award, which was presented for the first time last year, is given for "a distinguished engineering contribution which, through application proved in actual service, has advanced the art of transportation, whether by land, sea, or air."

Mr. Douglas has pioneered in many fields of aviation, but perhaps is best known throughout the world for his "DC" series of transport planes, including the twin-engined DC-3, workhorse of the commercial air lines for a decade. It was the most widely used passenger plane ever built, and many DC-3's are still in service throughout the world.

The 1955 award went to William Francis Gibbs, AFIAS, the naval architect and engineer who designed the S. S. "United States."

McDonnell Aircraft Corp. Forms Research Dept.

McDonnell Aircraft Corporation, St. Louis, has established a Research Department under supervision of Kendall Perkins, FIAS, Vice-President for Engineering.

Albert E. Lombard, Jr., FIAS, formerly with the Directorate of Research and Development, U.S. Air Force, has joined the company as Director of Research.

Concerning itself with problems of applied science and engineering research, the new department will supplement and contribute to work now being conducted in McDonnell's Airplane, Helicopter, and Missile Engineering Divisions and in the Flight Department.

"The Research Department," Mr. Perkins said, "will retain scientists of engineering bent and engineers of scientific bent who will be engaged in a variety of projects initiated either by the Government, by one of the engineering divisions, or by the Research Department itself if the projects offer sufficient promise of technical improvement in future aircraft and weapon systems.

"The new department is intended to help fill an ever-growing need for background technological information without which advanced aircraft and weapon

Albert E. Lombard, Jr.

systems cannot be developed effectively."

Dr. Lombard is a graduate of California Institute of Technology and former assistant professor of aeronautical engineering there. He became attached to USAF Headquarters, Washington, D.C., as a scientific adviser in 1949.

Ralph M. Parsons Company Joins the Institute

The Ralph M. Parsons Company, of Los Angeles, has joined the Institute as a Corporate Member.

The company's association with the aircraft industry dates back to 1921, when Ralph Parsons was in charge of testing aircraft engines for the Navy Bureau of Aeronautics. This work developed his interest in high-octane gasoline, and shortly thereafter he left the Bureau of Aeronautics to form his own company in Mt. Vernon, Ohio. This company engaged in the engineering, design, and construction of the first Dubbs cracking plants for the production of high-octane gasoline.

In 1937, Mr. Parsons became a partner in Bechtel-McCone-Parsons Corporation and, as Engineering Vice-President, led the company through the prewar and early war years, established and operated several large shipbuilding plants on the West and Gulf Coasts, and headed up the operation of the B-24 Modification Center at Birmingham, Ala.

In 1944, he founded The Ralph M. Parsons Company. Since that date, the company has been prominently identified with the petroleum and chemical industry and has pioneered the ultraforming method of reprocessing gasoline to produce high-octane aviation fuels. The company is deeply involved in research and development in connection with a heavy fuels program.

Along with the petroleum and chemical work in the early 1940's, the Company began extensive expansion into the design, construction, and operation of facilities for chemical-powered aircraft, guided-missile research, development and test facilities, large turboprop and jet-engine and rocket test stands, and missile launching sites.

The Company is presently engaged in producing master plans, facility criteria, and design of large nuclear-propelled-aircraft facilities throughout the United States for the Air Force, Navy, and Atomic Energy Commission. In addition, work in the fields of design of rocket propulsion facilities for the ICBM and IRBM program has continued to expand.

As a supporting operation, the Company has an Electronics Division located in Pasadena, Calif., which is devoted exclusively to research, development, and production of the electronic aircraft and missile erection components such as telemetering transmitters, telemetering decommutation stations, radar modifications for high accuracy, radar antennas, data handling and reduction equipment, and phototheodolite range timing and control systems.

USAF Research Office Moves

The Air Force Office of Scientific Research has moved from Baltimore to Building T, 14th Street and Constitution Avenue, Washington, D.C.

Brigadier General H. F. Gregory, AFIAS, is in command of the AFOSR, which is responsible for conducting an exploratory research program designed to provide new knowledge, the application of which may result in significant new concepts of air warfare. The Office lets research contracts to universities, research foundations, industry, and Government agencies.

General Gregory said the move will permit closer contact with the numerous scientific agencies located in Washington than was possible from Baltimore.

Wright Lecturer Chosen

Sir Arnold Hall, of London, England, a Fellow of the Royal Aeronautical Society, has accepted an invitation extended by the Institute of the Aeronautical Sciences to deliver the Wright Brothers Lecture on December 17 in Washington, D.C.

IAS Roster of Members

The Institute's "Roster of Members," published annually, will appear in the September issue of the REVIEW. In addition to listing the names and business affiliations of 11,000 graded members, the roster section will contain information on IAS membership, honors and awards, officers, committees, Sections, and Student Branches.

Necrology

Victor K. Muzik

Victor Klifton Muzik, MIAS, died May 28 in Los Angeles.

A native of Czechoslovakia, Mr. Muzik came to the United States soon after graduating from the University of Prague in 1922 as a Mechanical Engineer. He became an American citizen in 1929 but subsequently returned to Czechoslovakia for several years.

Mr. Muzik was employed as a Senior Stress Engineer by the Hufford Machine Works, Inc., El Segundo. He had been living in California since 1941. He is survived by his wife.

Replica of Lindbergh's Plane for Air Force Academy

Leland Hayward, producer of the motion picture *The Spirit of St. Louis*, said recently that he will give one of the replicas of Charles A. Lindbergh's airplane to the new Air Force Academy at Colorado Springs, Colo.

Three duplicates of the monoplane in which the "Lone Eagle" crossed the Atlantic were constructed for use in the film. Warner Bros. will use the planes for exploitation purposes during the summer, and then one of them will be placed on permanent exhibition at the Academy.

Brigadier General Charles A. Lindbergh, FIAS, is a member of the Board of Visitors of the Air Force Academy.

NEWS OF MEMBERS

▸ **Malcolm P. Ferguson** (AM), President of Bendix Aviation Corporation, has been named to represent the transportation equipment, aviation, and automotive parts industries on the National Advisory Council for a national exposition of new industrial products, methods, and research developments scheduled for October in Detroit.

▸ **George T. Hayes** (TM), Manager of the Washington, D.C., office of Stanford Research Institute, has been elected to serve on the Daniel Guggenheim Medal Board of Award. He will fill the unexpired term of Ralph S. Damon, deceased, as a representative of the American Society of Mechanical Engineers.

▸ **Joseph Rutkowski** (M), Associate Professor of Aeronautical Engineering, Wayne University, has been elected a Director of the Detroit Section of the American Rocket Society.

▸ **George H. Scragg** (M), Treasurer of the Early Birds, has received the Ameri-

can Legion Merit Award for his "lifelong contributions" to aviation. A number of aviation leaders and pioneer fliers attended the presentation by Air Service Post 501, New York, on April 24.

▸ **Harner Selvidge** (M), Director of Special Products Development, Bendix Aviation Corporation, has been elected a Director of the Detroit Section of the American Rocket Society.

▸ **Milton J. Thompson** (AF), Professor of Aeronautical Engineering and Associate Director of the Defense Research Laboratory at University of Texas, has been elevated to the rank of Fellow by The American Society of Mechanical Engineers.

▸ **Richard T. Whitcomb** (M), who won the Collier Trophy last year for discovering the "area rule" that helped reduce the transonic speed barrier, has received an honorary Doctor of Engineering degree from his alma mater, Worcester Polytechnic Institute. Mr. Whitcomb is Assistant Head of the 8-ft. Transonic Tunnels Branch at Langley Aeronautical Laboratory, NACA.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

H. Norman Abramson (M), formerly Associate Professor of Aeronautical Engineering in the Agricultural and Mechanical College of Texas, has been appointed Manager, Engineering Analysis Section, Southwest Research Institute, San Antonio, Tex.

Reuben D. Best, Jr. (TM), has been appointed Project Engineer on a helicopter stabilizer development project at Kellett Aircraft Corporation.

Herbert A. DeCenzo (M) has opened an office at 7046 Hollywood Blvd., Los Angeles, as a consultant to firms specializing in the production of aircraft couplings. He was formerly Chief Engineer of E. B. Wiggins Oil Tool Company, Inc.

Lester K. Fero (AF), formerly Chief of Structures, Bell Aircraft Corporation, has been promoted to Assistant Chief of Preliminary Design.

Hans R. Friedrich (AF) has been promoted to Chief Flight Mechanics Engineer with Convair, A Division of General Dynamics Corporation, at San Diego. He also has been appointed Visiting Professor of Engineering by the University of California in Los Angeles.

Rear Adm. Frederick R. Furth, USN (Ret.) (AF), has been elected a Vice-President of Farnsworth Electronics Company, a Division of International Telephone and Telegraph Corporation. The former Chief of Naval Research joined the company as

Clifford C. Furnas, FIAS, Asst. Secretary of Defense, R&D, has been presented the Honor Scroll of the Niagara Chapter of the American Institute of Chemists for "many years of distinguished service to academic and applied science."

Assistant to the President after retiring from the Navy last year.

Robert Goldin (AF) has been named Assistant Chief of Structures at Bell Aircraft Corporation. Previously, he headed the Criteria and Loads Group in the Structures Department.

Vernon D. Hauck (M) has been named Assistant General Manager of the Friez Division of Bendix Aviation Corporation, Baltimore. He was formerly Factory Manager.

Earl R. Hinz (AF) has been promoted to Chief of Systems and Controls, Engineering Division, Ryan Aeronautical Company. He was formerly a Research Group Engineer and Head of the Stability and Control Group.

Roy P. Jackson (M) has been appointed Assistant Chief Engineer of Northrop Aircraft, Inc. He was formerly Deputy Assistant Chief Engineer—Analytical.

Alexander H. Flax, MIAS, has been elected Vice-President for Technical Operations, Cornell Aeronautical Laboratory, Inc. Assistant Director—Technical for the past year, Mr. Flax won the IAS Sperry Award for 1949.

George W. Lober (M) has been appointed Sales Manager of the newly organized Microwave Electronics Division of Sperry Gyroscope Company Division of Sperry Rand Corporation. He was formerly Assistant Manager of Sperry's Seattle district office.

Robert J. Lutz (M), formerly of The RAND Corporation staff, has joined Convair, A Division of General Dynamics Corporation, as a member of the staff of R. C. Sebold, Vice-President for Engineering. He had been an engineer with Consolidated Vultee Aircraft Corporation prior to 1946.

George Mangurian (AF), formerly Chief of Structures, has been promoted to Chief Analytical Engineer of Northrop Aircraft, Inc.

D. B. "Ted" Martin (AF) has been named Director of Sales, Seattle Division, Boeing Airplane Company. He was formerly Manager of Military Sales for the Transport Division.

Harold C. Martin (M), Professor of Aeronautical Engineering, University of Washington, will be on leave of absence during the coming academic year. This summer he is associated with the Structural Dynamics Unit, Boeing Airplane Company. In September he will leave for Honolulu, where he will serve as visiting professor at University of Hawaii during the school year.

William C. McFadden (M) has been named Executive Vice-President of Hycon Manufacturing Company, Pasadena, Calif. He was formerly Vice-President and General Manager of the firm's Camera and Instrument Division.

John L. McLucas (M) has been elected a Director and Vice-President of Topp Industries, Inc., Los Angeles. He was formerly Vice-President of Haller, Raymond and Brown, Inc., an electronics research and development firm in State College, Pa., which was acquired recently by Topp Industries.

Kenneth F. Mundt (M) has been named Vice-President in charge of Manufacturing by Aerojet-General Corporation. He has formerly been Chief Engineer and Director of Manufacturing.

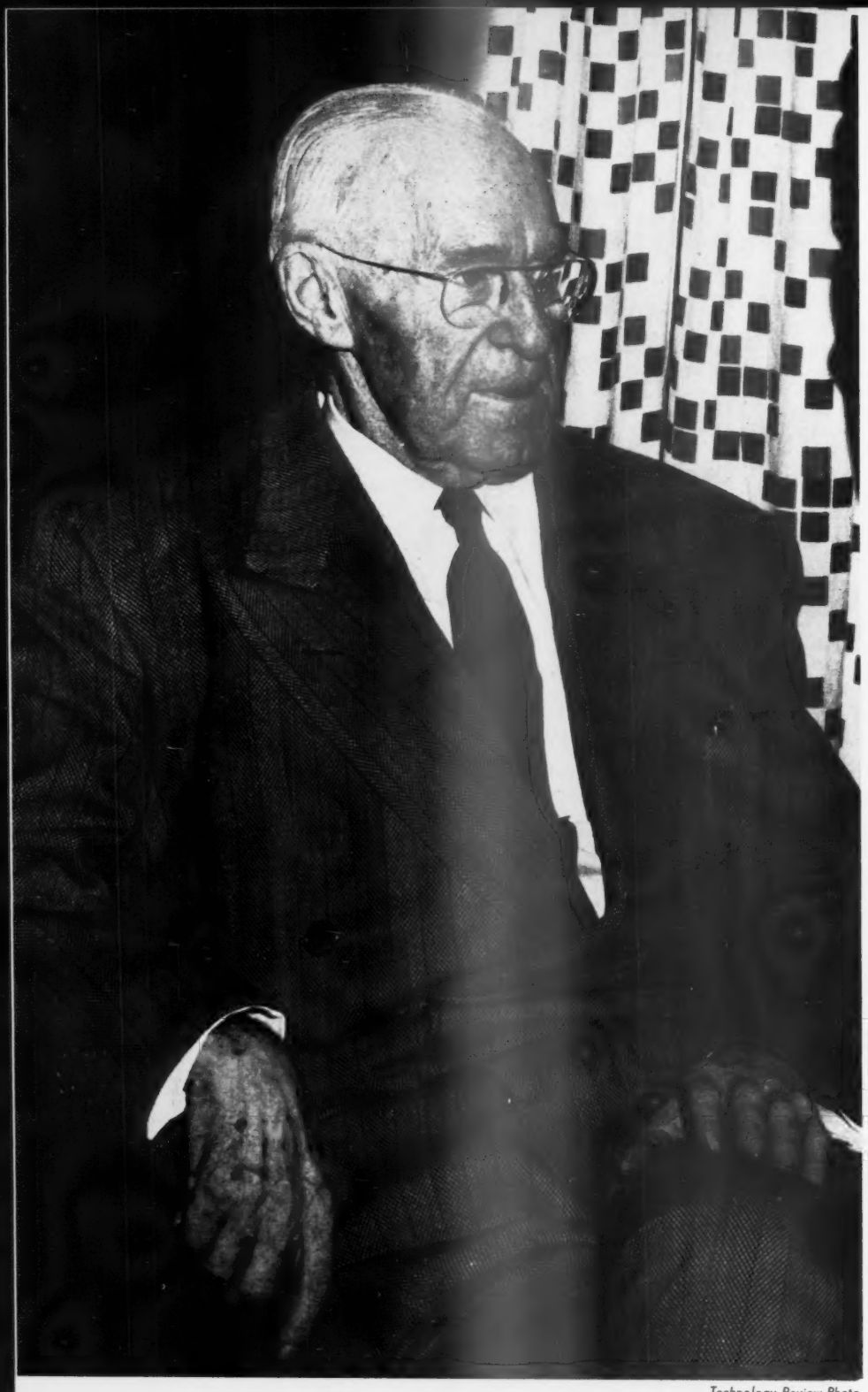
▸ **A. L. Paquette** (M) has been named Sales Manager of the Aircraft Equipment Department, Small Motor Division, Westinghouse Electric Corporation, Lima, Ohio. He was previously Manager of Field Sales.

W. A. "Dick" Pulver (M) has been named Assistant Chief Engineer of the Georgia Division of Lockheed Aircraft Corporation. He was formerly Chief Manufacturing Engineer of the California Division.

Thomas B. Rhines (M), Assistant Chief Engineer, has been appointed to the Operating Committee of Hamilton Standard Division of United Aircraft Corporation.

Robert B. Roe (M) has been appointed to the new post of Facility Planning Manager for the Aviation Division of Sperry Rand Corporation, Phoenix, Ariz. He was formerly Director of the Flight Research Department of Sperry Gyroscope Company.

(*Continued on page 62*)



Technology Review Photo

Editorial

Forty Years in Aviation. . .

On his Eightieth Birthday, Lester Gardner counts half of his total life in this aviation business. Founder of *Aviation* magazine in 1916, he ended active military duty in World War I as an Air Service Major. He organized the IAS in 1932 and retired from active participation in 1946. He is an Honorary Fellow of the IAS, a Guggenheim Medalist, and has been given many other honors at home and abroad.

. . .80 Years Young

On the seventh of this month, the Founder of this Institute attained the ripe age of Four Score Years. Now this in itself is not entirely unusual in these days when longevity more or less is the rule, but those of us who know Lester Gardner realize that his chronological age and his real age have little in common. For the last twenty-odd years, the remarks heard most frequently among his friends and associates have been, "I only hope that I have his 'get-up-and-go' when I am his age!" This still applies. The inevitable physical limitations of age sometimes retard the "get-up" part of it, but the urge to "go" is as strong as ever. An idea a minute is still his standard rate.

Another interesting point on the time scale, 1956 marks the fortieth year of Gardner's participation in aviation. Over half of his total life span has been devoted to aeronautics in one way or another. This puts him well back among the pioneers in this business. He began by founding *Aviation* magazine, a publication that ran under that name for 30 years until it became *Aviation Week* under McGraw-Hill.

We of the Institute owe much to Lester Gardner. He was the spark plug for that group of aviation people (including Hunsaker, Warner, Osborn, Loening, Wright, Doolittle, Aldrin, de Florez, and many others) who foresaw the need for a scientific and technical society for the aeronautical engineering profession and then undertook to *do* something about it. That was 25 years ago. Their work culminated in the founding of this society in 1932. Lester Gardner took over the arduous task of organization and financing.

In 1932 this was no easy task. Most of us can remember the problems of that period. The country was in the throes of the most crippling economic depression of all time. It was an era of political and social upheaval and unrest. Business generally was in the doldrums (or worse), and the aviation business was almost nonexistent.

Recall that in those days, a flight in an airplane was still considered a hazardous venture. Recall that this approximated the appearance of the first modern transport airplanes. Recall that the few machines in the hands of the military were slow and inefficient—many with uncowled engines and fixed landing gear—mounting a couple of 0.30-caliber machine guns. Recall that, in spite of the lessons of World War I, the airplane had not been accepted as an essential weapon in our national arsenal.

One bright spot in the picture was the existence of a small group of dedicated and devoted people either in, or associated with, the National Advisory Committee for Aeronautics. Led by George Lewis and spurred on by a hard core of zealots—the Hunsakers, the Warners, the Doolittles, *et al*—the NACA with the limited resources doled out to it by an unsympathetic Congress painstakingly laid the foundation and erected the framework on which the subsequent Air Age was built.

Significantly, the list of names of the men who were then most involved and the roster of the Founder Members of the IAS are virtually coincident. This was Lester Gardner's greatest contribution. Unless he had been able to integrate this group into a society for the propagation of the arts and sciences of aeronautics, he would never have been able (under the circumstances) to work the miracle of providing for its financial support. The number of shirt-fronts he drenched with his tears, the number of desks he pounded to splinters, the number of doorbells he rang in those days he alone can tell. We hope that he leaves us a personal record of that critical period when the life of the infant Institute hung many months in the balance. Some of the staff still remember long nights spent in inadequate offices, working on borrowed furniture to get out meeting announcements or to put together an issue of the then embryonic JOURNAL. Many a night, too, Lester's devoted wife, Margaret, kept the crew going on her coffee and doughnuts.

This was Lester's second greatest contribution. He breathed life into the organization and pumped the essential plasma, dollar by dollar, into its veins to tide it over a precarious infancy. For our very existence he must be given full marks. On his Eightieth Birthday we honor him for it and express our common appreciation for the work he did to make this organization possible.

It was his prior 20 years in aviation, as a publisher, as an Air Force officer, and as a promoter, that gave him the background and experience that have paid off so handsomely in this organization for which his energy and foresight provided such an excellent foundation.

At eighty Lester Gardner is as indefatigable as ever in attacking any problem that interests him, as those of us who tried to follow him in his recent campaign to raise funds for the Jerome C. Hunsaker Chair at M.I.T. can testify.

We all join in wishing him "many happy returns" and many more years of his active and useful life.

S.P.J.

Results of tests made with a heated tuning fork to determine damping by measuring the rate of vibration decay.

The Structural Damping of Titanium at Elevated Temperature

H. F. Hunter*
Lockheed Aircraft Corporation

Introduction

Recent interest in the structural application of titanium alloys to turbine blade and thin aircraft wing construction has prompted questions concerning the high-temperature damping capacity of these materials. Accordingly, an investigation of a representative alloy, Mallory-Sharon Titanium Corporation's 3Al-5Cr, has been conducted at the University of Maryland.† Damping data were obtained from a heated tuning fork specimen which was set into vibration by withdrawing a spreader from the gap between the fork ends. The results have been expressed in terms of the logarithmic decrement of the decaying oscillation, and the variation in modulus of elasticity with temperature was determined from the specimen vibration frequencies. Damping was found to vary with temperature, stress level, and vibration frequency. Both damping and modulus of elasticity variation with temperature were found to follow the same trend in the titanium alloy selected, as in 3.5 per cent nickel steel.

Damping may be determined by measuring the power required to sustain a specimen at an amplitude and frequency of vibration, by determining the shape of the response curve to a spectrum of forcing frequencies, or by measuring the rate at which a free vibration decays. The last method was selected for this investigation, using a titanium tuning fork specimen. This method offers advantages of simplified procedure, minimized energy loss to the support, and readily controlled stress and frequency parameters.

Similar determinations in the past have involved torsion and bending tests on vibrating rods, reeds, tubes, wires, and tuning forks. Bibliographies of literature on this subject are contained in references 1 and 2.

Test Procedure

A tuning fork was machined from a 1-in. diameter extruded billet of 3Al-5Cr titanium alloy (Fig. 1). A jig (Fig. 2) was constructed to mount the tuning fork and accommodate spreader bars of various widths which were withdrawn by a pivot arrangement from between the ends of the fork. The ensuing vibration was detected by a wire resistance strain gage and the signal recorded by an oscillograph. Stress levels were determined by suspending known calibration weights from the tip of the instrumented fork tine, and stress levels were varied during test by modifying the spreader bar width. A thermocouple-controlled electric furnace was used to heat the specimen to a uniform test temperature, and precise temperatures were monitored by a chromel-alumel thermocouple, with hot junction buried in the root of the fork.

All test results reported herein were obtained with a high-temperature strain gage currently under development by the Enameled Metal Group of the National Bureau of Standards. This gage consists

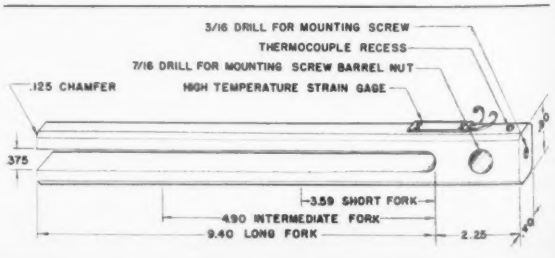


Fig. 1. Titanium tuning fork specimen.

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† Based on a portion of an M.S. thesis submitted in June, 1955. The author wishes to express appreciation to Professors Rivello and Shen of the Aeronautical Engineering Department, University of Maryland, for guidance in its preparation and to D. Moore of the Enameled Metal Section, National Bureau of Standards, for assistance with the high-temperature strain gage.

of two strands of heat-treated Karma wire, spot welded to Inconel foil lead tabs, which in turn are firmly attached to a thin asbestos paper backing. The gage, which is a self-contained unit, is attached to the specimen with a coat of ceramic adhesive. In the present work, Allen P-1 cement was used. The gage was attached and allowed to dry slowly, after which the fork was heated to the test temperature. The Inconel foil tabs were connected to gage lead wires by spot welding. The gages had resistances varying from 124.5 to 129.9 ohms and gage factors of 2.0 to 2.4. The Bureau of Standards design was found to be simple to apply and also rugged and reliable (Fig. 3).

Several commercial gages, as well as 30 hand-fabricated gages, individually assembled and mounted according to the techniques described in references 3 and 4, were used in preliminary testing. The following observations on high-temperature strain-gage applications were made after experimentation with the various types:

(1) Hand fabrication of gages for dynamic measurement is laborious when compared to the application of prefabricated gages of the National Bureau of Standards design.

(2) Simple friction contact electrical connections in strain-gage circuits are unsatisfactory at high temperatures since variation in contact resistance develops from oxidation.

(3) High-temperature strain-gage connections can be made with the greatest ease, speed, and reliability by spot welding.

(4) Heat-treated Karma wire exhibits little thermal drift up to temperatures of approximately 800°F. and is a satisfactory gage material for dynamic measurement.

(5) The strain-gage factor is influenced by the thickness of cement between gage and specimen. In the bending strain measurements, gage factors tended toward higher values as cement thickness increased.

Data Reduction and Accuracy

Data reduction was accomplished by measuring the maximum amplitudes of successive vibration cycles and plotting these data on semilog paper as a function of number of cycles. Damping, expressed as the logarithmic decrement, was calculated from the relationship $\delta = (1/N) \ln_e (A_0/A_n)$, where δ is logarithmic decrement, A_0 is initial vibratory cycle double amplitude, A_n is nth cycle double amplitude, and N is number of cycles.

When only viscous damping is present in a material, the double amplitude of vibration is a pure exponential which becomes a straight line when plotted against number of cycles on semilog paper. Coulomb damping, or static sliding friction, is characterized by a concave downward shape on a semilog plot, while turbulent damping (proportional to higher powers of velocity) may be distinguished by a concave upward shape. The characteristic slight concave upward shape of the

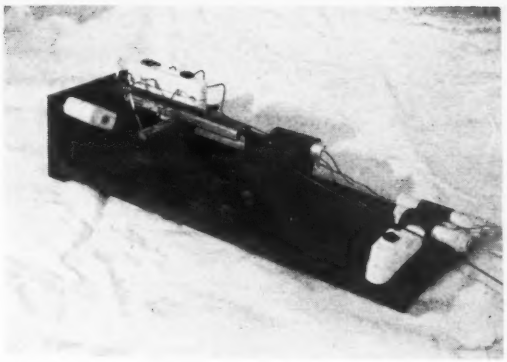

Fig. 2. Test jig, short tuning fork, and high-temperature strain gage.

decay curves (Fig. 4), shows the hysteresis damping to be predominantly viscous in character, with a small content proportional to higher powers of velocity.

Variation in elastic modulus with temperature is readily obtained from the decay oscillograms. The square of the natural frequency ratio of a vibrating specimen at any two temperatures is equal to the ratio of the moduli of elasticity at those temperatures.

It should be noted that the bending stresses reported herein correspond to average outerfiber strains existing at the gage location. These inertia bending stresses are not constant over the gage length, hence they are referred to as nominal maximum bending stresses.

Several complications arose in analyzing the decaying transient to arrive at damping values:

(1) Failure of the spreader to release both tines simultaneously resulted in occasional beating or periodic reinforcing and diminishing of the decay envelope.

(2) First harmonic oscillations were superimposed upon the fundamental, in all measurements involving the long tuning fork.

(3) Small errors inherent in scaling the amplitudes of vibration made the evaluation of a large number of cycles necessary.

(4) The predominant viscous nature of hysteresis damping observed was complicated somewhat by the presence of higher order (turbulent) damping. This introduced curvature into the decrement plots, reducing the accuracy of the calculated values by an estimated 2 to 3 per cent, as a consequence of constructing tangents to determine local slope.

With regard to failure of the spreader to release the tines simultaneously, the random nature of this occurrence suggested that it may have been the result of an off-center pull of the trip mechanism, foreign matter on tines or spreader, or eccentricity and free play in the trip linkage. This disturbance died away after several hundred cycles and in only a few extreme cases negated the usefulness of the initial portion of the record. In less severe cases, the maximum and minimum beat amplitudes were averaged to obtain a mean value. The validity of this procedure rests on the supposition that energy is eventually dissipated

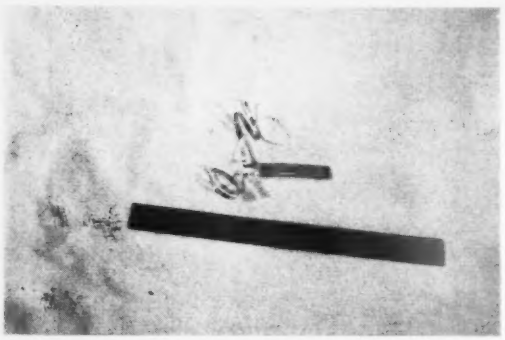

FIG. 3. Bureau of Standards prefabricated high-temperature strain gage.

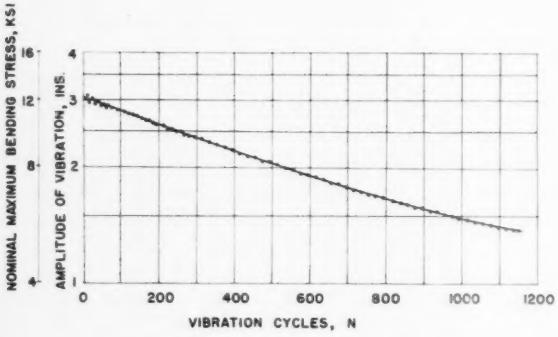

FIG. 4. Typical decay history.

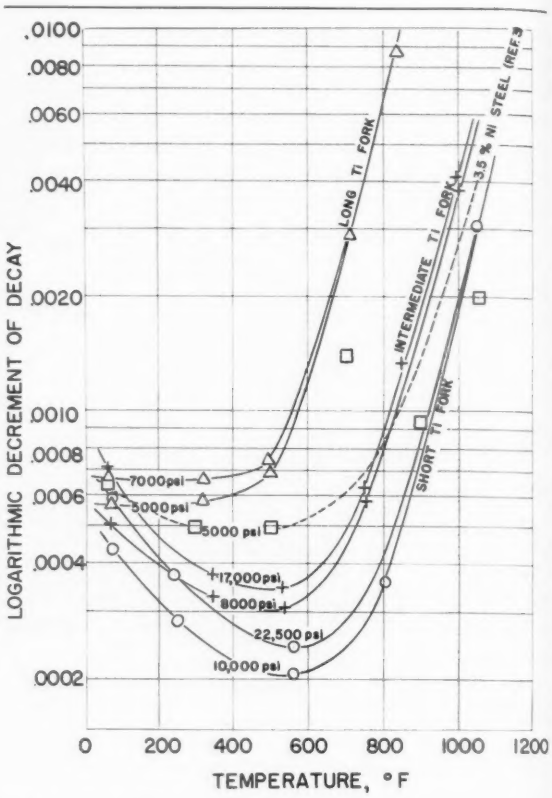

FIG. 5. Variation in titanium damping with temperature and stress level.

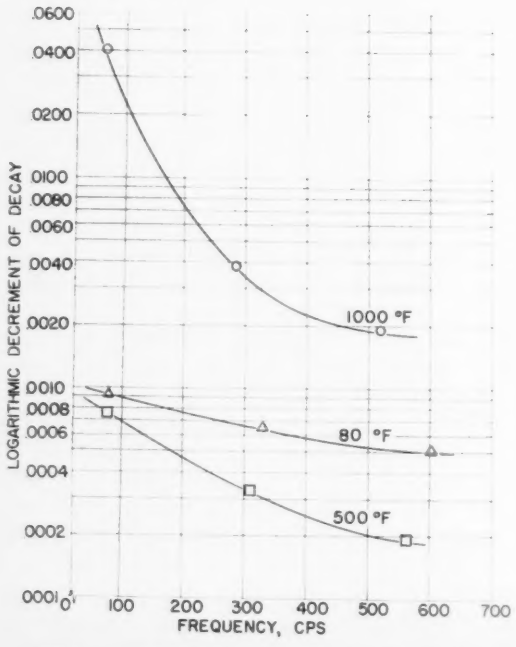

FIG. 6. Effect of frequency on titanium damping.

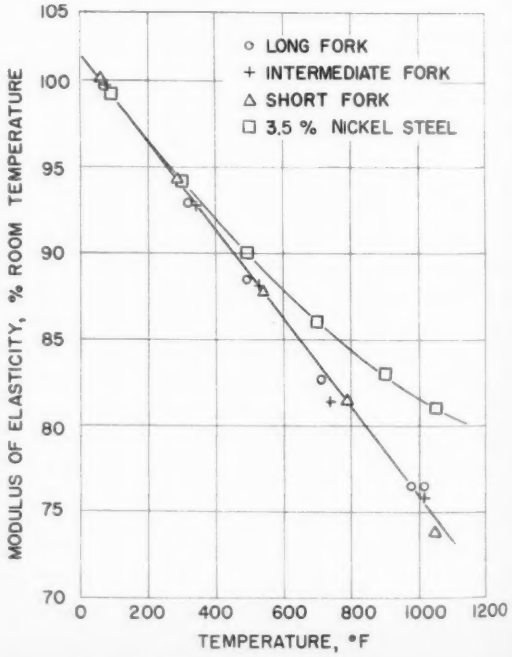

FIG. 7. Variation of dynamic elastic modulus with temperature.

equally between the tines since it results from a wandering of energy between them.

Two complications arose as a result of first harmonic bending responding with the fundamental: (1) The resulting wave form required harmonic analysis to yield amplitudes in each mode of vibration, and (2) the total damping had to be distributed between the two oscillations. Several numerical types of harmonic analysis were abandoned because of complexity and tediousness, and a visual method was employed to define the amplitude of the fundamental.

The last two items concern accuracy of measurement and may be considered simultaneously. The largest component of error in the damping values is due to error in scaling the amplitudes of vibration from the oscillogram and in drawing tangents to the decay curves. The plots of amplitude versus number of cycles are neither straight lines nor absolutely smooth curves. The deviation from a smooth curve is due in part to inexactness in plotting the scaled amplitudes, particularly between values of 1 and 2 in., where errors are magnified in consequence of the expanded logarithmic scale. Extreme care did not entirely eliminate this waviness, which in instances could be traced directly to the oscillogram. Several irregularities of this sort appeared at approximately periodic intervals, indicating extremely low amplitude fork beating. In other cases, the decay appeared to occur in extremely gentle steps, rather than at a uniformly varying rate. These amplitude irregularities were of the order of 0.010 in. Scaling to this accuracy on photographic paper is made difficult by the fuzziness of the photographic emulsion and must be done with the aid of a magnifying glass and a finely (0.02 or 0.01 in.) graduated scale.

Since these small irregularities did not affect the predominant slope of the decay curve, a greater number of amplitudes were scaled and a line faired through the plotted points for better definition.

Some variation in constructing successive tangents to the same point on the decay curves was noted, giving rise to another source of error. The estimated maximum deviation in damping due to scaling and tangent error is estimated to be ±5 per cent.

Other sources of error may arise from energy losses outside of the tuning fork and from nonlinearity between the specimen vibration amplitude and the recorded amplitude. The fork showed the same damping supported in the jig as when suspended from a fine nylon thread, and, while this does not eliminate all question of losses to the support, it does indicate that they are extremely small. The specimen displayed the same damping value with a gage on one tine as with a gage on both tines, indicating no appreciable loss of energy to this source. Linearity between strain and recorded amplitude was investigated by observing the trace deflection resulting from known bending moments, at temperatures up to 1,000°F. A linear relationship was observed in all tests with satisfactory gages.

The temperature and strain values reported are believed to be accurate within ±5 per cent and the logarithmic decrements of decay within ±10 per cent.

Results

Figs. 5 and 6 present summary curves of decay rates, with data on 3.5 per cent nickel steel for comparison. A typical stress history, from which the summary damping plots were constructed, is shown in Fig. 4. In the range of parameters tested, damping always increased with stress level and decreased with frequency. The former trend is characteristic of homogeneous structural engineering materials in general. However, a frequency lower than 25 cycles per sec. probably exists at which damping is a maximum and below which damping decreases.[5] Short and intermediate length tuning forks displayed minimum damping at approximately 500°F., while the long fork showed a relatively constant minimum value between 80° and 500°F. This behavior has been noted in other materials and is associated with metallurgical effects discussed by Zener.[6]

The values of decay rate obtained were limited at higher temperatures by the yield strength of the material and at frequencies higher than 600 cycles per sec. by limitations of the recording equipment. Rapid, accurate measurements at temperatures above 1,000°F. would require a well-sealed and insulated furnace, with rapid heating rate governed by a sensitive thermocouple control, in order to minimize drafts and uneven heating in the furnace cavity.

In summary, the log decrement of decay was found to vary between values 0.0002 and 0.04, at temperatures between 80° and 1,000°F., bending stresses between 1,000 and 29,000 psi, and frequencies between 87 and 600 cps. The dynamic modulus of elasticity variation was calculated from ratios of measured frequencies and was found to vary linearly with temperature, displaying approximately 75 per cent of room temperature value at 1,000°F.

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A semiempirical method based upon simple theoretical foundations; results of the design charts are compared with available experimental data.

Prediction of Downwash at Various Angles of Attack for Arbitrary Tail Locations

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Symbols

- a = vertical distance from plane of tip vortex cores to the horizontal tailroot chord in the plane of symmetry, ft.
- b = wing span, ft.
- b_e = effective wing span, ft.
- b_v = span of wing tip vortices at a given longitudinal station, ft.
- b_{vru} = span of the completely rolled up wing tip vortices, ft.
- l_{t1} = tail length, measured in the wing root chord plane, from the wing root trailing edge to the $c/4$ of the tail mean aerodynamic chord, ft.
- l_{t2} = tail length, measured in the wing chord plane, from the tip vortex quarter chord to the $c/4$ of the tail mean aerodynamic chord, ft.
- h_{t0} = tail height, measured perpendicular to the wing chord plane, from the wing chord plane to the $c/4$ of the tail mean aerodynamic chord, ft.
- ξ_{ru} = distance required for complete rollup of the wing tip vortices, measured along the wing chord plane from the tip vortex quarter chord, semispans
- ξ = longitudinal distance aft of wing root trailing edge, measured in wing chord plane, semispans
- Λ = sweepback angle of wing quarter chord line, deg.
- λ = wing taper ratio, tip chord/root chord
- γ = wing dihedral angle
- ϵ = downwash angle, rad.
- ϵ_{vc} = downwash angle in the plane of symmetry at the vertical height of the tip vortex cores, rad.
- $\bar{\epsilon}$ = downwash angle in the plane of symmetry at the vertical height of the $c/4$ of the tail mean aerodynamic chord, rad.
- ϵ_t = average downwash angle at the tail, rad.
- C_L = wing lift coefficient
- C_{D_0} = wing zero lift drag coefficient
- C_D = wing drag coefficient
- R = wing aspect ratio, b^2/S
- S = wing area, sq.ft.
- R_e = effective wing aspect ratio, b_e^2/S_e

Introduction

With the advent of aircraft which fly at supersonic speeds, one might surmise that the aerodynamic design problems of these aircraft at low speeds would be routine. However, such is not the case. Both sweepback and very thin airfoil sections, which permit high-speed flight, affect low-speed flight characteristics adversely.

In particular, the swept wing tends to tip stall, leading to pitch instability at high angles of attack. This deficiency may be corrected by a well-designed horizontal tail, properly located in the downwash field of the wing. Therefore, the aircraft designer has a need for a method to predict the nonlinear downwash variation which the horizontal tail experiences.

The purpose of this paper is to present a method for the prediction of the downwash angle for arbitrary wing-tail combinations throughout the complete range of angle of attack. The method is intended for use in preliminary design, prior to the availability of wind-tunnel results for the configuration. A prime requirement, therefore, is that the downwash prediction be made by a simple, easily applied procedure. It is recognized, of course, that a compromise may be required in the rigor of the procedure in order that it may be used with facility. The path followed in the development of the subject method was to employ simple theoretical relationships as a basis to evolve a graphical procedure for the evaluation of the downwash.

Development of Method

The downwash at the tail surfaces is a consequence of the trailing vortex system associated with the lifting wing. Consequently, it appears appropriate to consider the trailing vortex system to recall some of its primary characteristics before discussing the development of the procedure itself.

Nature of the Trailing Vortex System

The trailing vortex system behind a swept wing is sketched in Fig. 1. A vortex sheet is shed by the lifting wing, and the sheet is deflected downward by

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the bound or lifting vortex and the tip vortices which comprise the vortex system. The sheet, in general, is not flat, but the curvature near the wing midspan is usually relatively small. This is particularly true of the straight wing of reasonably large aspect ratio for which the central portion of the vortex sheet is extremely flat. Wings with considerable trailing-edge sweepback produce a vortex sheet which is bowed upward near the plane of symmetry.

The tip vortices do not experience a vertical displacement of the magnitude of the central portion of the vortex sheet. In general, they trail back comparatively close to the streamwise direction. Furthermore, as the vortex system proceeds downstream, the tendency is for the tip vortices to move inboard. Also, with increasing distance behind the wing, the trailing sheet vorticity tends to be transferred to the tip vortices. The transfer of vorticity and inboard movement of the tip vortices takes place in such a fashion that the lateral center of gravity of the vorticity remains at a fixed spanwise location. When all of the vorticity is transferred from the sheet to the trailing vortices, the vortex system is considered to be fully rolled up, and, in a nonviscous fluid, the vortex system would then extend unchanged to infinity.

Ahead of the longitudinal station for complete rollup, the spanwise downwash distribution is dependent upon the spanwise lift distribution of the wing. However, when the rollup is complete, the downwash angles for all wings of equal lift and effective span are identical. It is evident that the shape of the vortex sheet has a significant influence on the downwash experienced by a tail located in the flow field of a wing and that the tail location relative to the trailing vortices is all important. Since the tip vortices are somewhat above the vortex sheet, the downwash above the sheet is somewhat more than the downwash beneath the sheet.

The tip vortices spring from the wing tips at angles of attack for which the flow is unseparated. However, wings with high sweepback angles tend to stall at the tips, and the tip vortices originate well inboard of the wing tip at high angles of attack in many instances. This phenomenon has a significant influence on the downwash at the tail.

The previous discussion has been concerned with wings which behave in a somewhat conventional manner at high angles of attack. However, certain thin, highly swept wings have a significantly different flow pattern in the higher angle of attack range. These wings are characterized by a leading-edge separation vortex which lies above the surface of the wing. From its inception near the plane of symmetry, it moves outboard in the approximate direction of the wing leading edge and is finally shed in a streamwise direction near the wing tip. Reference 9 shows some interesting studies of the separation vortex. It is clear that the existence of this vortex will have an important influence on the downwash and that it requires special consideration for the prediction of the downwash at the tail.

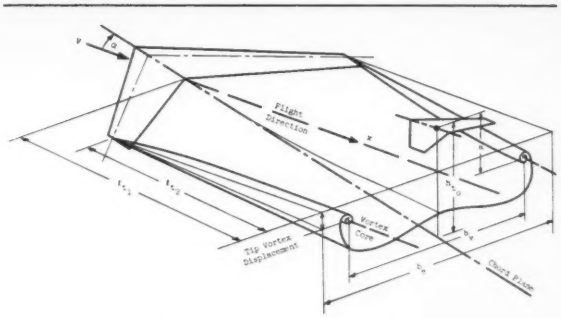


FIG. 1. Wing vortex system.

Determination of Maximum Symmetry Plane Downwash

The basic approach to the downwash prediction employed in this paper is to

(1) Determine the downwash in the symmetry plane at the height of the tip vortices at the longitudinal station of the tail M.A.C. quarter chord.

(2) Correct this value for tail height above the vortices.

(3) Evaluate the effect of tail span by relating the average downwash at the tail to the downwash determined from step 2.

The flow direction in the plane of symmetry is readily determined at two longitudinal stations: At the wing trailing edge, it is along the chord line; and at distances far downstream of the wing, the downwash velocity is due only to the fully rolled up tip vortices. Glauert[8] gives the following value for the downwash angle for an elliptically loaded wing with fully rolled up tip vortices:

$$\epsilon = (1.62\ C_L)/\pi R \tag{1}$$

This downwash angle is experienced at the vertical position of the tip vortices. In order to relate the downwash angle with the angle of attack, we make use of the following expression for the lift curve slope from simple sweep theory:

$$\partial C_L/\partial\alpha = (2\pi R \cos\Lambda)/(R + 2\cos\Lambda) \tag{2}$$

Eqs. (1) and (2) may be combined to give

$$\partial\epsilon/\partial\alpha_\infty = (3.24 \cos\Lambda)/(R + 2\cos\Lambda) \tag{3}$$

Eq. (3) is plotted in Fig. 3.

As previously indicated, $\partial\epsilon/\partial\alpha = 1.0$ at the wing trailing edge. The next step then is to approximate the longitudinal downwash variation between these limiting stations. In order to accomplish this, use will be made of the horseshoe vortex concept of the lifting line theory. With the assumption of an unswept, uniformly loaded, constant chord wing, the lifting and trailing vortices contribute to the symmetry plane downwash in the following manner:

$$\epsilon_{\substack{\text{lifting}\\\text{vortex}}} = \frac{(cC_l/4\pi)}{X\sqrt{1 + (2X/b)^2}}$$

$$\epsilon_{\substack{\text{trailing}\\\text{vortices}}} = cC_l/\pi b \tag{4}$$

The downwash slope then becomes

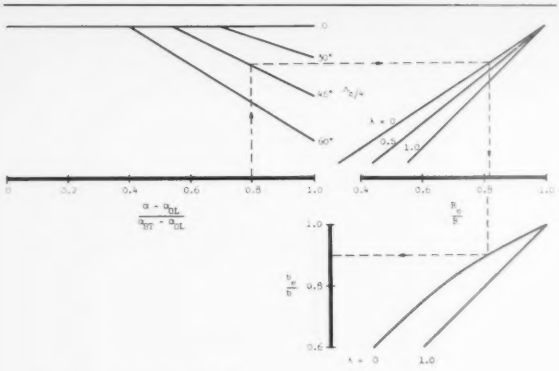


FIG. 2. Variation of effective aspect ratio and span ratio.

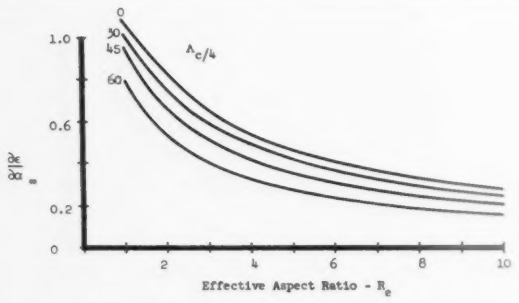


FIG. 3. Variation of $\partial\epsilon/\partial\alpha$ in the symmetry plane at the height of the vortex cores for fully rolled up vortices.

$$\frac{\partial\epsilon}{\partial\alpha} = \frac{R/(R+2)}{(2X/c)\sqrt{1+(2X/b)^2}} + \frac{2c}{b}\frac{R}{R+2} \qquad (5)$$

In obtaining Eq. (5), use was made of the expression for $\partial C_L/\partial\alpha$

$$\partial C_L/\partial\alpha = 2\pi R/(R+2)$$

Noting the $\partial\epsilon/\partial\alpha = 1.0$ at the trailing edge, we may solve for the particular distance, X_0, that the lifting line must be located forward of the trailing edge to satisfy this condition. Setting Eq. (5) equal to 1.0, we obtain the following expression:

$$R(2X_0/b)\sqrt{1+(2X_0/b)^2} = 1.0 \qquad (6)$$

from which $2X_0/b$ may be determined as a function of the aspect ratio. The contribution of the lifting vortex to the downwash varies with longitudinal distance aft of the wing trailing edge in the following manner:

$$\frac{\Delta(\partial\epsilon/\partial\alpha)}{\Delta(\partial\epsilon/\partial\alpha)_{\substack{\text{trailing}\\ \text{edge}}}} = \frac{2(X_0/b)\sqrt{1+(2X_0/b)^2}}{\left[\frac{2X_0}{b}+\frac{2X}{b}\right]\sqrt{1+\left[\frac{2X_0}{b}+\frac{2X}{b}\right]^2}} \qquad (7)$$

For the purposes of this analysis, it has been found convenient to express the downwash slope at any arbitrary longitudinal station as follows:

$$\partial\epsilon/\partial\alpha = (\partial\epsilon/\partial\alpha)_\infty + \Delta(\partial\epsilon/\partial\alpha)_{\substack{\text{lifting}\\ \text{vortex}}} \qquad (8)$$

Since $\partial\epsilon/\partial\alpha = 1.0$ at the wing trailing edge, the contribution of the lifting vortex to the symmetry plane downwash at a tail location $2l_{t_1}/b$ semispans aft of the root chord trailing edge is

$$\frac{\Delta(\partial\epsilon/\partial\alpha)_{\substack{\text{lifting}\\ \text{vortex}}}}{1-(\partial\epsilon/\partial\alpha)_\infty} = \frac{(2X_0/b)\sqrt{1+(2X_0/b)^2}}{\left[\frac{2X_0}{b}+\frac{2l_{t_1}}{b}\right]\sqrt{1+\left(\frac{2X_0}{b}+\frac{2l_{t_1}}{b}\right)^2}} \qquad (9)$$

Eq. (9) is plotted in Fig. 4 for several values of aspect ratio.

Thus far in the discussion, no consideration has been given to nonlinear aerodynamic behavior, and Eqs. (3) and (9) are suitable for use at angles of attack for which the flow is essentially unseparated. It is necessary, however, to correct for the effects of separation at high angles of attack. As mentioned previously, swept wings are subject to tip stall, and the tip vortices tend to move inboard, thereby causing a reduction in the effective aspect ratio of the wing. Since the relation between induced drag and aspect ratio is well defined, it seems likely that an effective aspect ratio may be deduced from the induced drag measurements on a given configuration, using the relation

$$R_e = C_L^2/[\pi(C_D - C_{D_0})] \qquad (10)$$

This was done for several untapered wings of varying sweepback reported in reference 7. A definite pattern appeared when R_e/R was plotted versus a nondimensional angle of attack parameter $(\alpha - \alpha_{OL})/(\alpha_{ST} - \alpha_{OL})$. A progressively larger reduction of effective aspect ratio at high angles of attack was noted as wing sweepback increased. The effective and geometrical aspect ratios were identical at low to moderate angles of attack for all values of sweepback. The onset of the effective aspect ratio reduction occurred at smaller values of the angle of attack parameter as the sweepback became larger. Analysis of data for wings of zero taper ratio confirmed these findings, and, as would have been anticipated, the reduction in effective aspect ratio was even more severe for the highly tapered wings.

Working curves for the determination of R_e/R as a function of angle of attack, sweepback, and taper ratio are given in Fig. 2. The validity of this basic approach is strengthened by reference 3, which presents water tank measurements of the lateral position of the vortex core behind an elliptical straight wing of aspect ratio 5 and a triangular wing of aspect ratio 2. The vortex core paths behind the straight wing are nearly independent of angle of attack. For the triangular wing, the vortex span at an angle of attack of 32° is approximately 70 per cent of the vortex span at $\alpha = 8°$ at a longitudinal station two spans downstream of the trailing edge.

From geometrical considerations, it is clear that the effective span change for a given effective aspect ratio change is a function of the wing taper ratio. Evaluation of the effective span ratio in terms of effective aspect ratio and taper ratio may be made with the following expression:

$$b_e/b = \frac{2(R_e/R)}{1 + \lambda + [(R_e/R)(1 - \lambda)]} \qquad (11)$$

Fig. 3 includes a chart to determine b_e/b, using the above equation.

In the use of Eqs. (3) and (9), the effective aspect ratio must be employed.

Correction of Symmetry Plane Downwash for Tail Height

The effect of tail height on the downwash in the symmetry plane is a function of the degree of rollup in the vortex sheet at the tail location under consideration. For a location at the height of the tip vortices, the symmetry plane downwash behind an elliptically loaded wing is[8] $\epsilon = 2C_L/\pi R$ for the flat vortex sheet, and $\epsilon = 1.62C_L/\pi R$ for the fully rolled up vortex system.

The comparison of downwash values at infinity for various tail heights for both types of vortex system is shown in Fig. 5. The tail height parameter, $2a/b_e$, is the ratio of the vertical distance of the tail above the vortex cores to the effective semispan. It may be seen from Fig. 5 that there is very little effect of the rolling up of the vortex sheet at values of $2a/b_e$ in excess of ± 0.2. For all practical purposes, the downwash may be considered independent of the degree of rollup. However, at the height of the vortex cores, the flat sheet has nearly 25 per cent more downwash than the fully rolled up vortex system. For the purposes of the present paper, it will be assumed that the vortex sheet is fully rolled up at the tail location. It is recognized that this is far from the case for many practical configurations.

Since the intersection of the plane containing the tip vortices with the plane of symmetry will establish the location of the maximum symmetry plane downwash, the correction for tail height will, in all cases, reduce the downwash. The ratio of the symmetry plane downwash at the tail height in question, $\bar{\epsilon}$, to the previously computed downwash at the vortex core height, ϵ_{rc}, is given as

$$\bar{\epsilon}/\epsilon_{rc} = 1/[1 + (2a/b_v)^2] \qquad (12)$$

where b_v is the vortex core span at the tail location.

The determination of the vertical distance of the tail above the vortex cores requires a knowledge of the displacement of the vortex cores relative to the free-stream direction. It is possible to determine this displacement from a consideration of the horseshoe vortex system. At points far downstream, each of the trailing vortices is deflected downward only by the influence of the other. The symmetry plane downwash from the rolled up tip vortices behind an elliptically loaded wing is given by Eq. (1) [$\epsilon = (1.62\ C_L) \div \pi R_e$].

The downwash, of course, results from the two vortices, each of which is one half of the vortex span from the plane of symmetry. The distance of one trailing vortex from the other is the full vortex span, and, since each vortex is displaced only by the other, the vertical displacement of the vortex cores is one fourth the displacement of the flow at the plane of symmetry. Thus, the displacement angle of the vortex cores in the vertical plane is given as $(0.41\ C_L)/\pi R_e$.

Therefore, the distance a is calculated as

$$a = h_{t_0} - l_{t_{2_e}}\{\alpha - [(0.41\ C_L)/\pi R_e]\} - (b_e/2)\tan\gamma \qquad (13)$$

where

$l_{t_{2_e}}$ = longitudinal distance from $c/4$ of the effective tip to $c/4$ of the tail M.A.C.
h_{t_0} = tail height above the chord plane extended
γ = wing dihedral angle

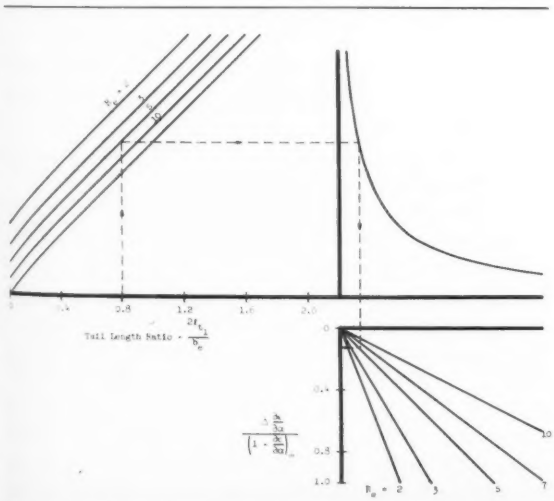


FIG. 4. Variation of symmetry plane downwash with tail length.

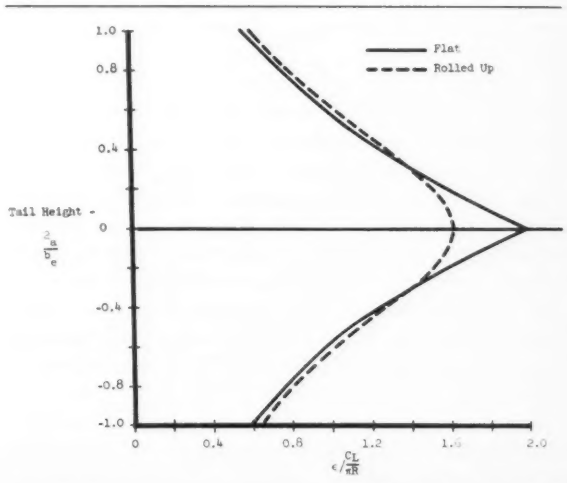


FIG. 5. Comparison of downwash at infinity for flat and fully rolled up vortex systems behind an elliptically loaded wing.

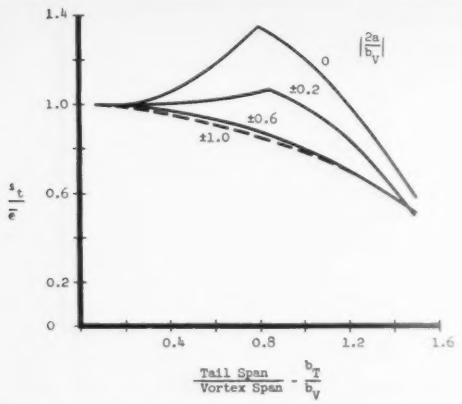


FIG. 6. Effect of tail span and tail height on the downwash angle at the tail.

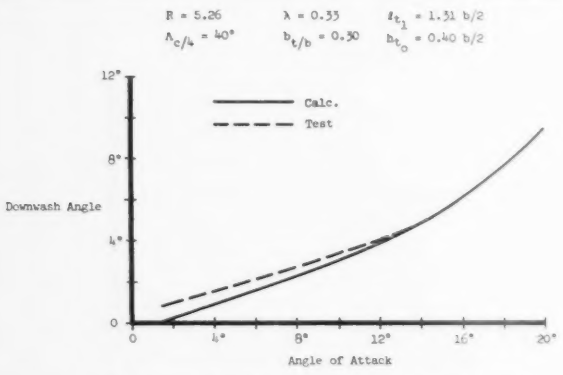


FIG. 7. Comparison of test and calculated downwash angles.

The tail height above the vortex cores for conventional flow patterns is given with sufficient accuracy by the treatment described above. However, wings which have a leading-edge separation vortex must be handled somewhat differently since the leading-edge vortex is well above the wing surface when it has progressed to the trailing edge. Thin, highly swept wings of low aspect ratio generally possess a leading-edge separation vortex at most angles of attack.

For the purposes of the calculation of the tail height relative to the vortex core, our experience has been that the vortex may be assumed to start at the leading edge of the wing M.A.C. for low aspect ratio delta wings. It is considered to be depressed through the angle $(0.41\ C_L)/\pi R_e$, as is the usual tip vortex. The leading-edge separation vortex does not move straight aft in the streamwise direction from its inception near the wing root; rather it flows in a spanwise direction toward the wing tip[9] and leaves the trailing edge at a spanwise location approximating the effective span ratio from Fig. 2.

For the case of the leading-edge separation vortex, the distance a is calculated as

$$a = h_{t_0} - (l_{t_1} + X_{LE})\{\alpha - [(0.41\ C_L)/\pi R_e]\} - b_e/2 \tan \gamma \quad (14)$$

where X_{LE} is the distance from the leading edge of the M.A.C. to the trailing edge of the root chord.

The remaining parameter to be evaluated for the calculation of the effect of tail height on the symmetry plane downwash is the vortex span b_v. It is known that the tip vortices from an elliptic straight wing roll up so that the vortex span when rollup is complete is 0.785 of the geometrical wing span. However, the data for swept wings[5, 6, 9] show a much reduced rollup tendency. There are not sufficient published data available to establish the rolled up vortex span in the general case. However, the following empirical formula will yield a reasonable approximation of the completely rolled up vortex span:

$$b_{v_{ru}} = 0.78 + 0.10(\lambda - 0.4) + 0.003\ \Lambda_{c/4} \quad (15)$$

In order to determine the vortex span between the wing and station for complete rollup, the following relation may be employed:

$$b_v = b_e - (b_e - b_{v_{ru}}) \left[\frac{\frac{2l_{t_{2_e}}}{b_e}}{\frac{\xi}{\xi_{ru}}}\right]^{1/2} \left(0 < \frac{\xi}{\xi_{ru}} < 1\right) \quad (16)$$

ξ_{ru} is the distance aft of the tip quarter chord required for the tip vortices to roll up. An analysis made by Kaden yields the following value for ξ_{ru}:

$$\xi_{ru} = 0.56\ R/C_L \quad (17)$$

Eqs. (12), (13), (15), and (16) are employed to evaluate the effect of tail height on the downwash in the symmetry plane for the case of normal tip stall. When the leading-edge vortex is present, Eq. (14) is substituted for Eq. (13).

Effect of Tail Span on the Downwash at the Tail

The effect of the tail span on the effective downwash at the tail has also been determined under the assumption that the vortices are essentially rolled up at the tail location. It is believed, however, that this assumption will not impair the general utility of the procedure for several reasons:

(1) Rollup is slow for high aspect ratio wings, but, for these wings, it is unusual to have a large ratio of tail span to wing span.

(2) Rollup is accelerated at high lift coefficients, for which the downwash values are large.

(3) For usual values of tail span to wing span, there is not a large difference between the results using the rolled up or nonrolled up approaches.

The curves of Spreiter[3] were recast in a form suitable for the present purpose and are presented in Fig. 6.

It should be noted that, for tail locations near the plane of the vortices, large increases in effective downwash are experienced when the tail span approximates the vortex span. As the tail is raised or lowered appreciably from the vortex plane, the effect of increased tail span is to reduce the average downwash at the tail.

Comparison of Calculated and Experimental Downwash Values

The downwash variations for several representative configurations have been computed and compared with experimental values and are shown in Figs. 7, 8, 9, and 10. Wings of widely different plan form were selected to evaluate the ability of the procedure to predict the downwash angle for the general configuration.

The wing of Fig. 7 is a 40° swept wing of aspect ratio 5.26. It is representative of a plan form with considerable trailing-edge sweepback. The chosen tail location is 0.40 $b/2$ above the chord plane extended, and the typical increase in $\partial\epsilon/\partial\alpha$ associated with high tails at high angles of attack is evidenced in both the test and calculated results. The comparison between the calculated and test values of downwash is considered to be good.

Fig. 8 compares the downwash from an unswept wing of aspect ratio 10. The tail length was 0.50 $b/2$ and the tail height 0.13 $b/2$. Again, the comparison between test and calculated data is good. The downwash curves are relatively linear throughout the angle of attack range.

The third sample configuration (shown in Fig. 9) is a triangular wing of aspect ratio 2.31. The leading-edge separation vortex is a characteristic of this wing. Two tail heights were investigated: -0.87 $b/2$ above the wing plane and -0.06 $b/2$ below the wing plane. A range of angles of attack up to 32° was considered. A glance at Fig. 8 indicates the extremely large effect of tail height on the downwash at high angles of attack. At $\alpha = 32°$ there is a difference in downwash of approximately 26° between the test values for the high and low tails. The calculated values show a difference of approximately 24°. The discrepancy between calculated and test values of downwash is about 4° in the case of the high tail and 2° for the low tail configuration. The trends in the downwash are predicted quite well by the calculations.

The configuration of Fig. 10 provides an example for which the prediction of the downwash was not quite so satisfactory. The wing configuration employed 45° of quarter chord sweepback, and the aspect ratio was 5.1.

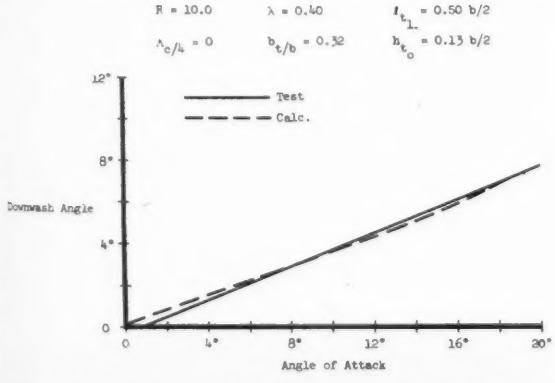


Fig. 8. Comparison of test and calculated downwash angles.

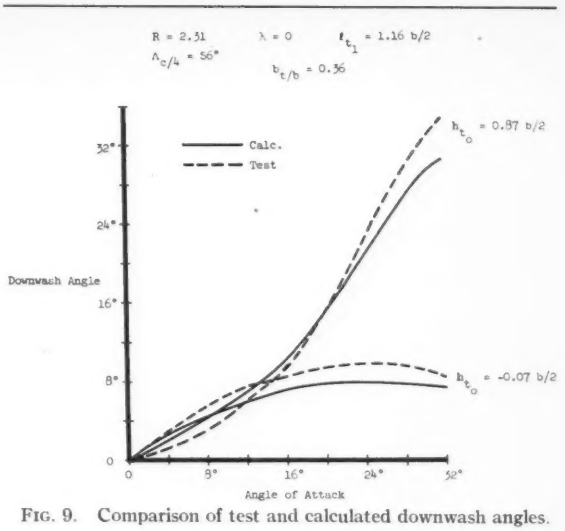


Fig. 9. Comparison of test and calculated downwash angles.

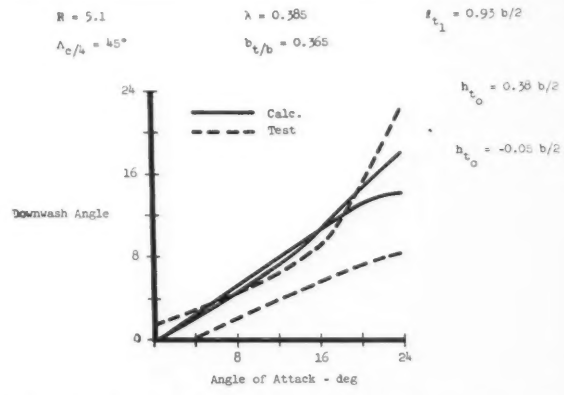


Fig. 10. Comparison of test and calculated downwash angles.

The tail length was short—the longitudinal distance from the wing tip quarter chord to the tail M.A.C. quarter chord was only one third of the wing semispan. The downwash at high angles of attack with the high tail was somewhat more than predicted. Since the vortices are undoubtedly not rolled up, and the calculated tail position is near the vortex height, this discrepancy may be accounted for by considering the downwash for the flat vortex sheet. If this is done, near-perfect agreement is obtained. The low tail presents another problem since the computed downwash is high. This may possibly result from the sharp contraction of the aft fuselage on the model.

In general, it appears that the method will predict the downwash angles experienced at the horizontal tail with accuracy acceptable for preliminary design purposes. The method should be suitable for the comparison of configurations and for studies to determine the best location of the horizontal tail on a particular configuration.

It should be remarked that the present study has been restricted to the flaps-up case. The procedure, how-

(*Continued on page 61*)

Comdr. A. L. Rasmussen,* USN

The New Naval Aviation Safety Program

Safety as engineered into Navy air operations is paying dividends of 10,000 per cent annually, but the Naval Aviation Safety Center still seeks "added thrust."

Introduction

During the past 2 calendar years, the U.S. Navy has reduced its major aircraft accident rate by two accidents for every 10,000 flight hours. This is quite an astounding feat when one stops to consider that Naval fliers log several million hours annually. The saving in lives and in aircraft are both counted in the hundreds, meaning that the combat efficiency of Naval aviation has been significantly improved and that several million tax dollars have been saved. The effect on morale through improved safety, reduced repair bills, and greater materiel reliability has been substantial. The Navy air arm truly has adopted a new safety program.

How did all this come about? The cold fact is that it was an extremely carefully planned and executed tactical maneuver backed by the Secretary of the Navy and the Deputy Chief of Naval Operations for Air.

In July, 1952, the Naval aircraft accident rate was 5.5 accidents per 10,000 flight hours, having been steady to slightly increasing for 3 fiscal years. The Naval Aviation Safety Program then consisted essentially of the forwarding of accident reports via the chain of command plus the monthly publication in the *Naval Aviation News* of two pages of safety philosophy written by "Grampaw Pettibone," ostensibly the oldest and wisest (though mythical) Navy pilot.

This obviously is not a complete picture; however, there admittedly was a need for major revision of the Naval aviation safety effort. Little could be done with the large volume of aircraft accident reports being received. Modern aircraft were becoming more complex and expensive. This was a prime time for action.

Establishment of Naval Aviation Safety Center

The Chief of Naval Operations established the Naval Aviation Safety Activity (now the Naval Aviation Safety Center) at Norfolk, Va. in the middle of 1952. With a small number of officers, civilians, and enlisted personnel, the general functions of this activity were to (1) receive and process all Naval aircraft accident reports, (2) publish a quarterly statistical summary of accident information, and (3) publish a weekly summary of aircraft accidents with additional notes and comments.

A typical wreckage layout utilized by Naval Aviation Safety Center investigators to determine accident causes.

It was immediately obvious to this group that further steps were necessary if the accident rate was to be reduced significantly. Still supported by the Secretary of the Navy and the Chief of Naval Operations, the Naval Aviation Safety Center since has been expanded twice with additional funds and personnel. And so have its mission, tasks, and functions.

Simply stated, the Center is organized: "To collect, evaluate, and disseminate information pertaining to aviation safety; to review or prepare for the Chief of Naval Operations directives, issuances, and other correspondence for the advancement of aviation safety; to prepare and promulgate aviation safety literature; to conduct periodic aviation safety surveys; to conduct special investigations of aircraft accidents; and to advise the Chief of Naval Operations on all phases of the aviation safety effort in order to maintain the highest practicable level of aviation safety."

* Head, Maintenance & Material Dept., Naval Aviation Safety Center, Norfolk, Va.

Requirements of Aviation Safety

Establishment and implementation of the Naval Aviation Safety Center did not in itself reduce the Naval aircraft accident rate. Aviation safety is an "all hands" function requiring the utmost cooperation of all commands and activities to assist the central monitoring agency. By the proper evaluation of aircraft accident, forced landing, incident, and ground accident reports, it is possible to detect unsafe conditions or deficiencies in the three basic elements which make up aviation: (1) human beings, (2) airplane hardware, and (3) operational utilization of (1) and (2).

Through the detection of such inadequacies, significant corrective action can be initiated for the improved design, manufacture, operation, and maintenance of aircraft. Necessary advancements in training are readily established. The need for improved safety and survival equipment is detected. Weaknesses in our systems for obtaining corrective action have been uncovered, generating the need to improve methods to attain greater efficiency. And thus, through the actions and reactions of processing reports of unsafe occurrences and conditions, aviation safety has found a front seat in the Navy in a short 2 years.

During this 2-year period, several major accomplishments have been made which are essential to the Naval aviation safety program.

Aviation Safety Officer's School Established

One of the first deficiencies discovered in the processing of accident, forced landing, incident, and ground accident information was the inadequacy of investigations. It was immediately determined that aircraft accident boards were not well enough trained in the methods of cause determination. Many aircraft accidents went into the undetermined files through lack of knowledge of investigation procedures, and it was evident that proper corrective measures could not be taken unless cause factors were definitely established.

Some of the Naval Aviation Safety Center's publications vital to life and materiel conservation are viewed by the author.

Captain M. B. Williams, Director of the Naval Aviation Safety Center *(right)*, and the author confer.

In order to correct this serious situation, the Naval Aviation Safety Officer's School was established at the University of Southern California in 1954. An 8-week course teaches rudiments of accident investigating and reporting. Besides approximately 80 classroom hours in investigating, plus an actual field investigation, the following courses are covered (totaling approximately 260 classroom hours): basic aeronautical engineering, aviation psychology, aviation physiology, and safety management.

Nearly 200 graduates of this school are now on duty in fleet aviation safety billets and are currently conducting the quality investigation and reporting necessary to aviation safety. Recently many civilian contractors and members of other activities have become interested in the Safety School and are sending their representatives to a condensed course of instruction. It is expected that it will be continued as an essential part of the Naval Aviation Safety Program.

Much of the information essential to accident investigation is published in the *Handbook for Aircraft Accident Investigation*, which is distributed Navy-wide for such use.

Accident Reporting System Improved

Almost as soon as the Safety Center was established, it was determined that accident reporting procedures needed revision. Work was begun immediately to improve and correct existing deficiencies. Adequate message reports of unsafe occurrences and amplifying information in accordance with a prescribed form were established. Instructions for the appointment of accident boards, adequacy of the reporting form, duties of the chain of command, and many other items were reviewed and improved as necessary. These items are now published in the "bible" of Naval aviation safety which is *Navy Aircraft Accident, Incident, and Forced Landing Reporting Procedure*, Op Nav Instruction 3750.6B. This instruction contains complete information for the reporting of all Naval aircraft accidents, forced landings, incidents, and ground accidents.

A suspected hydraulic component is discussed by the author *(right)* and Lt. Comdr. H. N. Moore, crash investigator.

"FUR" System Inaugurated

An extremely frustrating barrier to the new Naval Aviation Safety Program was the lack of background statistical information on materiel failures which *did not* result in aircraft accidents.

The Unsatisfactory Report (UR) system, which had replaced the old Report of Unsatisfactory or Defective Materiel (RUDM) system in 1952, could not be processed by machine methods, nor did it have workable provisions for rapid emergency reporting.

In 1954 the Safety Center and the Chief of Naval Operations, in cooperation with the Bureau of Aeronautics, sparked the establishment of a new method for the rapid reporting and processing of failure information—the Failure or Unsatisfactory Report (FUR) system. It utilizes modern IBM machinery in conjunction with microfilm (filmsort) to process incoming failure reports, currently being received at over 1,000 per day. Obviously not all of these reports relate to Safety of Flight, but it is easily seen that such a volume of valuable and diversified information can be processed only by modern machine methods.

The system also has a rapid message reporting form which is required on all Safety of Flight failures. This assures priority action on all such failures. Previous facilities prevented positive and rapid determination of unsafe conditions in many instances until after an accident had occurred. In several cases, multiple accidents occurred before the problem was isolated and corrected. The FUR system greatly limits the probability of accidents due to the same or similar failures.

The FUR system has been primarily responsible for the detection and correction of many unsafe conditions, thus preventing several serious aircraft accidents which might have otherwise occurred. It is the most modern and efficient method of obtaining failure statistics and data in operation in the world today and is an essential part of the new Naval Aviation Safety Program. Materiel reliability cannot be obtained without such a system. The current directive promulgating instructions for FUR reporting is BuAer Instruction NavAer 00.58A.

Disassembly and Inspection Report (DIR) System Improved

In many instances of known or suspected materiel failure, the facilities available to perform complete investigations at the squadron level are inadequate. Therefore, it is essential to have technical specialists and equipment available to perform any needed materiel investigations and establish and report the cause of failure. Many cases of disassembly in the field have resulted in negative findings, further damage to equipment, and loss of evidence.

Under the improved DIR system, any investigation board can contact the nearest BuAer Maintenance Representative who designates an activity to which the failed equipment is to be sent. This is usually an Overhaul and Repair Activity, but in the case of brand new equipment it would probably be the contractor. The equipment is sent by the fastest means available, and utmost priority is given to the tear down and report.

Instructions for the proper procedures to follow are promulgated in the FUR Instruction. The mechanics of the system are simple, and it has proved a vital asset in the determination of cause factors plus the correction of materiel deficiencies.

Quality Aviation Safety Literature Published

The publication of adequate safety material to form a continuous flow of information to all levels of the aviation organization is an essential part of any aviation safety program. The original *Weekly Summary of Accidents* is still published with maintenance safety notes and highlights of the week's reported accidents. In addition, a full-length, quality safety magazine called *Approach* is published monthly. This magazine has many articles of interest to all individuals concerned with aviation. It is divided into three sections—operations, aeromedical, and maintenance.

Approach is available on a subscription basis from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., at $2.50 per year.

A quarterly *Digest of Accidents Involving Materiel Failures and Maintenance Errors* is published Navy-wide with comments and appraisals of some of the more important information. A quarterly *Digest of Forced Landings, Incidents, and Ground Accidents* is also published. These digests contain information alphabetically by model aircraft and are a major source of information to aviation safety officers. By avoiding the occurrences and investigating or expecting the troubles listed, any aviation activity can materially reduce the probability of an unsafe occurrence. History has proved that most unsafe occurrences are periodic repeaters. Some occur only a few times in the lifetime of an aircraft—which we can live with—and others much more frequently—which we cannot live with. Notification to all activities concerned is essen-

tial, whether or not the unsafe condition is corrected, so that plans can be made to avoid known hazards.

In addition, the Naval Aviation Safety Center publishes *Accident Summaries* for specific models of aircraft at intervals; also safety posters. "Grampaw Pettibone" is still a plank owner in the Naval Aviation Safety organization, and his articles appear monthly in *Naval Aviation News* published by BuAer. This publication is also available on a subscription basis.

There is no doubt that the publication of this quality literature has done much to sell the new Naval Aviation Safety Program. Continuation and improvement of all safety publications is essential to the progress of safety.

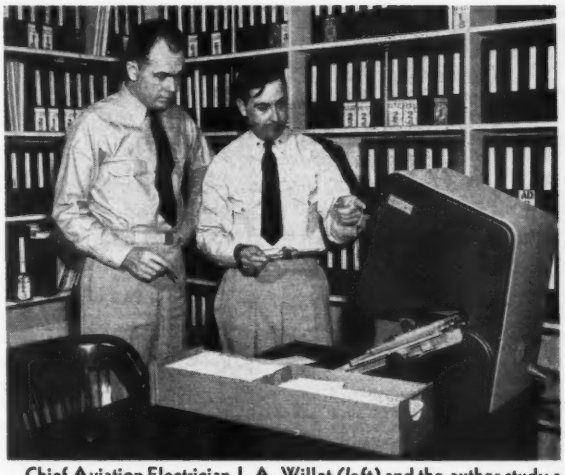
Aeromedical Aspects Improved

Certainly the greatest problem in the entire safety program is the human being. Realizing this, the Naval Aviation Safety Program has shown the need for highly qualified flight surgeons in accident investigations. Current instructions for accident boards require that one member be a flight surgeon. Investigation of the sociological, psychological, and physiological factors has proved extremely important in aircraft accident prevention. Pathological investigation is also proving to be a major source of information in accident cause determination. Such factors are studied and coordinated by the Aeromedical Department of the Center.

There are many more accomplishments of less dynamic significance which add up to a major contribution to the aviation safety effort. These involve the mechanics of the Safety Program and are deleted from this account only in the interest of brevity.

Conclusion

In conclusion, it is obvious that Naval aviation safety has come a long way over the past 2 years. The major aircraft accident rate has been significantly reduced, resulting in the saving of many lives and aircraft. The Navy has made a determined effort which has succeeded.



Chief Aviation Electrician J. A. Willet *(left)* and the author study a microfilmed Safety of Flight AMPFUR (an amplified FUR) on a magnification viewer.

Still, there are many avoidable accidents occurring daily which involve the design, manufacture, operation, and maintenance of Naval aircraft. Therefore, there is much to be accomplished in the future. Is the present safety effort satisfactory? Is it worthy of continuation? Should the efforts be expanded in view of the tremendous expense involved? The answer in each case is a firm "yes"! And here are the reasons:

(1) In view of the increasing cost and complexity of modern aircraft, additional efforts are not only warranted but desperately essential. As we approach closer to our goal (as any good football player knows), our task becomes increasingly difficult, and added thrust is essential.

(2) "A penny saved is a penny earned" is a poor proverb in safety. Figures show that every dollar *spent* directly on Naval aviation safety for the past 2 years saved us approximately $200 in reduced accidents. This is a fantastic 10,000 per cent annually on our investment. An ounce of prevention in this instance was worth many pounds of cure.

(3) Naval aviation recognizes its responsibility in the conservation of lives and dollars and is prepared to continue and implement its safety efforts.

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Considerable savings in suction power requirements can be realized by using distributed suction in contrast to single slot systems.

Delay of the Stall by Suction Through Distributed Perforations*

August Raspet,† Joseph J. Cornish III,‡ and Glenn D. Bryant**
Aerophysics Department, Mississippi State College

Introduction

Experimental demonstration of boundary-layer control to delay separation was first made in 1904 by Prof. L. Prandtl[1] in a beautifully simple manner. He used a small, slow-speed, hand-driven water channel in which he placed a cylinder having a lengthwise slot cut into the convex wall. To the interior of the cylinder led a rubber hose. By cranking the water wheel to obtain a flow and siphoning on the hose, Prandtl was able to photograph the delay of separation when the slot was rotated to a position on the downstream face of the cylinder. This experiment was conducted outside Prandtl's small laboratory because neither fast film nor intense lights were available, but the bright sun was.

The influence of Prandtl's experiment was not felt, however, until some years later when Ackeret, Betz, and Schrenk[2] made their studies on a boundary-layer controlled wing. Prandtl's philosophy of single slot suction has persisted even to the present in spite of the fact that Prandtl[3] himself gave the relation for rate of momentum gain ΔM in the boundary layer with distributed suction as $\Delta M = \rho U_0 v_0$, where U_0 is the outer velocity, v_0 is the suction inflow velocity, and ρ the fluid density. In 1926 Ackeret[4] mentioned distributed suction in a diffuser having walls of perforated plate. Ackeret pointed out the advantages of a perforated wall diffuser but made no measurements. Later one of his students, Ras,[5] studied rather extensively the control of the boundary layer in a diffuser having perforated plate walls of uniform porosity.

In the meantime, Schrenk[6] in 1928 made an experimental test of sheet perforated with narrow, short slots and with holes installed on the suction surface of an airfoil. In fact, Schrenk even divided the wing into three compartments in order to apply suction through the slot-perforated sheet in a manner requiring less suction power.

Much later, Shenstone[7] discussed the advantages of suction boundary-layer control through perforations and described an airplane using this concept to increase lift and to reduce pressure drag of the wing, as well as that of the wing root. Furthermore, he used the suction air to cool the engine. An airplane was built along these lines by Miles,[8] but evidently the results obtained were not promising for nothing but sketchy data were reported.

In contrast to the limited use of distributed suction for stall delay, the use of a slot at one chordwise position on the airfoil has received considerable attention. Chordwise positions from the leading edge to the very trailing edge have been recommended. Walz[9] showed that for a single slot the position of maximum lift increase for a given suction quantity $\Delta C_L/C_Q$ was at about 10 per cent. This result applies to an NACA 0012 airfoil at $RN = 0.8 \times 10^6$. By far the greatest effort, however, has been expended on the suction or blowing slot at the flap and aileron hinge point. A most elegant work in the single slot boundary-layer control field was that of Stüper[10] in which he reported the work at Göttingen on the AF-1 and AF-2 boundary-layer control airplanes. A variation of the single slot scheme resulted in the combined suction-blowing of Arado of which there have been several recent applications. The work reported in this paper will be confined to the process of suction boundary-layer control by suction distributed by means of rows of perforations spaced chordwise in such a way that a boundary layer stable against turbulent separation is maintained to the trailing edge with a minimum expenditure of suction power. This scheme was tested on a sailplane and on an Army L-21 Cub of 125 hp. The results of take-off measurements made with the L-21 show clearly that the suction through distributed perforations improves the take-off

Presented at the VTOL Aircraft Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* This work was conducted under a research contract with the Office of Naval Research under the sponsorship of the U.S. Army.

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‡ Aerodynamicist.

** Aeronautical Engineer.

over a 50-ft. obstacle by 42 per cent. Comparisons made with the data of Stüper show further that distributed suction is much more economical of suction power than single slot suction.

Concepts of Distributed Suction BLC

The process of stall delay in the flow over an airfoil consists essentially of bringing energy into the boundary layer by removing the slower innermost volume of the boundary layer. In view of the fact that the turbulent boundary layer exists over the rearward positions on the upper surface of any airfoil, the process of stall delay on these wings consists in delaying the separation of the turbulent boundary layer. Advantages of this procedure lie in the ability of a turbulent boundary layer to flow against a larger adverse pressure gradient and in the fact that small geometric disturbances need not be considered as insurmountable obstacles as they must in the process of laminar stabilization. In other words, the present status of the control of the geometry of airfoils on production aircraft allows the process of turbulent boundary-layer control to be considered, provided seams, rivets, and gross disturbances are eliminated. This is not a strict requirement except where a maximum economy of suction power is desired. In the application of single slot suction or blowing where considerable energy is added at one chordwise point, where the boundary layer is actually "repaired," geometric discontinuities are not considered as serious detriments, for additional power can be added to make up for losses suffered by the boundary layer upstream.

Recognizing the potential of the distributed suction control of the turbulent boundary layer, the authors of this paper sought a rational method for designing suction surface airfoils which would yield the largest lift increment for the smallest suction power along this line. Cornish[11] made a study of various high-lift devices with a view toward defining their properties. His results showed that a plain airfoil yielded the best value of power factor $C_L^3/C_{D_t}^2$. This value then remains as a goal for boundary-layer control research.

An even more rigid criterion and a practical one is evinced by this stipulation:

> Effective boundary-layer control is achieved when the airplane whose suction power is taken from the main engine shows a better take-off over 50 ft. than when the same power is used for propulsion. In other words, effective boundary-layer control must show that the suction power is better used for boundary-layer control than when left in the propeller.

How much power can be so stolen from the propeller or propulsion unit depends on the reserve power available for climb. How little needs to be taken depends on the efficiency of the boundary-layer control system.

The foregoing power considerations no longer apply for landing over an obstacle because on landing the engine has an excess of power. However, when the suction is obtained from stored power, as is desirable for safety, power economy is again a strong consideration.

Schweizer TG3-A Modified for High-Lift BLC Research

In October, 1953, work was begun to modify a TG3-A sailplane for use as a research vehicle. This sailplane has a wing area of 237 ft.^{2} and an aspect ratio AR = 12.5. Most of the research was conducted with the sailplane at a wing loading of 5.2 lbs./ft.^{2}. After modifications and while in the impervious condition, this aircraft developed a maximum lift coefficient of 1.38 which occurred, under the above conditions, at an air speed of 38.5 m.p.h.

The wing was structurally reinforced to allow perforations to be drilled. In order to strengthen the plywood D-beam and compensate for the weakening effect of the perforations, Fiberglas cloth was bonded to the wing. Experiments with sample specimens showed that the strengthened, perforated wing was approximately 10 per cent stronger than the original unperforated wing.

Since the wings were divided into two compartments by the spars, two suction pumps were required for each wing. The pump in the forward compartment was capable of operating at a high-pressure differential in order to achieve the suction required. The rear pump was required to produce a pressure differential of fewer inches of water because of the lower local velocities over the rear portion of the wing.

With the final porosity on the wings, the sailplane was able to develop an airplane lift coefficient C_L = 2.28 with a suction quantity C_Q = 0.00316. At this condition, the airplane stalled at 29.8 m.p.h.

L-21 Modified for High-Lift BLC

The L-21 is a military liaison-type adaptation of the familiar Piper Super Cub Model PA 18. This airplane is a tandem two-place tractor monoplane. It is provided with a strut-braced, high, rectangular wing and a two-wheel landing gear. Wing span is 35 ft., and wing area is 178 sq.ft. Gross weight is 1,500 lbs. The structure consists of a steel tube truss fuselage and a wing made from two extruded aluminum spars and aluminum truss ribs covered with fabric. Propulsion is provided by a Lycoming 125-hp. engine driving a 72-in. fixed-pitch metal propeller.

The principle guiding the modification was to apply boundary-layer control to the airplane to test it in a take-off and minimum flying speed configuration. The landing and cruise conditions were considered secondary. An engine-driven blower was, therefore, considered desirable because of its simplicity, even though boundary-layer control would not be available for a power-off landing. A fixed-pitch propeller set for take-off and climb was also selected for simplicity.

Design of the BLC System for the L-21

The application of boundary-layer control to the L-21 was intended primarily as a test of the engineering applicability of the techniques and methods thus far developed. The required suction, a suitable pump, and

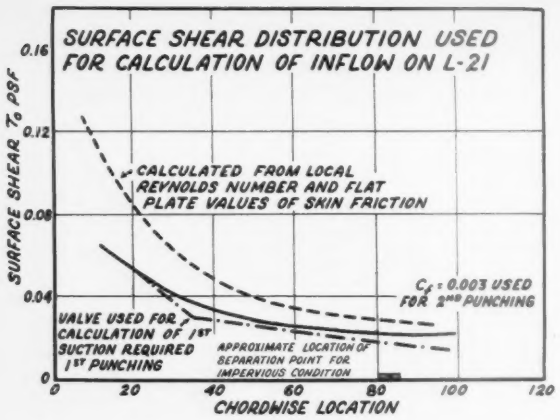

FIG. 1. Surface shear on L-21 wing.

all other necessary accessories were to be designed from an initial set of measurements, and the results were to be evaluated on the basis of lift gained for horsepower expended. The design of the system was separated into three steps—distribution and amount of suction required, pressure losses in ducting and turns, and pressure and flow requirements of pump.

In order to determine the suction quantities required, a procedure similar to the one reported in reference 11 was followed. This method makes use of the von Kármán momentum equation written by Prandtl to include the effects of suction at the surface

$$\theta = \frac{U}{U'(H+2)}\left[\frac{C_f}{2} + \frac{v_0}{U} - \theta'\right] \qquad (1)$$

From the previous research it has been found that a considerable delay of separation and a consequent increase in lift could be accomplished if the rate of loss of momentum in the boundary layer could be inhibited. In the present case, it was decided to limit the growth of the momentum thickness to 0.002 ft. per foot. This amounted to allowing the boundary layer to grow only about one half as fast as in the impervious case.

The use of Eq. (1) requires a knowledge of the boundary-layer parameters, the surface shear, and the velocity distribution which will exist on the wing after the application of suction. A major factor influencing these parameters is the chordwise location of the point at which suction is started.

Since the wing of the L-21 is fabric covered and has a metal leading edge which extends back to the 15 per cent chord station, this location was chosen as starting point for the suction. Although mechanically desirable because of the ease of punching the fabric covering, this position is also suitable from an aerodynamic standpoint. It is far forward enough to achieve control of the boundary layer with relatively small flow quantities, and yet the suction pump is not required to work against a high-pressure rise.

In order to determine the terms to insert in Eq. (1), measurements were made on the wing with the airplane in flight at 38 m.p.h. At this speed, the turbulent separation point was between the 80 and 85 per cent chord stations, and the flap was completely stalled in all cases except the 0° position.

Boundary-layer profiles were measured on the upper surface, and from these the initial value of momentum thickness at the 15 per cent chord was computed. The local velocity along the surface was also measured. It was assumed that the value of the shape parameter H would remain constant at 1.45 under the influence of suction. The values of the surface shear used in this computation are shown in Fig. 1.

The required flow for this suction distribution was obtained by drawing the air through rows of 0.030-in. holes punched in the wing. The spacing of these perforations was determined by the internal wing pressure, the flow characteristics of the holes, and the required inflow. The highest allowable internal wing pressure was fixed by the local static pressure at the 15 per cent chord station. For, if at any point the internal wing pressure were higher than local static pressure, outflow would occur at that point. In the practical case, however, the pressure inside the wing should be considerably lower than the lowest local static pressure. This should be done to avoid extremely close row spacings in regions where the pressure difference across the skin would otherwise be very low. In this case, the internal wing pressure was chosen so that the minimum pressure difference across the skin would allow a spacing of at least 0.1 in. between rows of holes. With the internal wing pressure thus determined and the flow coefficients of the holes known, the spacing of the rows to give the correct suction distribution was computed. However, when the airplane was flown, it was found that two discrepancies were present. First, due to shrinkage of freshly doped fabric, the flow coefficient of the holes was lower than the value used in the computations. Secondly, the internal wing pressure developed by the pump was not so low as had been calculated. Consequently the actual inflow quantity was much smaller than was computed. This distribution gave a lift increment of 0.25 with a value of C_Q = 0.00125 at 36 m.p.h. It was decided that a second porosity distribution should be calculated taking into account the reduced pressure drop inside the wing and the reduced flow coefficient of the holes in the wings. It was further decided to prohibit entirely the growth of the boundary layer at 38 m.p.h. in order that a larger lift increment be gained. For this computation, a constant value of skin-friction coefficient C_f = 0.003 was used. After the new row spacing was calculated, the additional porosity was punched onto the wing between existing rows already on the wings. The new inflow distribution required a suction coefficient C_Q = 0.00354.

The new arrangement yielded a lift increment of 0.90 above the impervious case which brought the speed down to 34 m.p.h. This value was still not so good as could have been expected from previous research,[11] where amplification factors $\Delta C_L/C_Q$ = 285 were obtained. It was obvious that, while the momentum

equation was useful in predicting the required suction distributions, some additional information concerning the variation of the momentum thickness and the shear in the boundary layer under the influence of suction was required.

Concurrently with the project of applying perforated suction to the L-21, a more fundamental research was being conducted using the sailplanes. This research was directed toward a better understanding of the effects of suction on the boundary-layer parameters. Although the study was not complete at this time, enough information has been obtained to allow some insight into the prediction of the effects of suction on the momentum thickness of the boundary layer.

Therefore, a third suction distribution based on the results of the new research was planned. The row spacing determined by this method was applied to the aircraft in much the same manner as the previous distributions. This new suction distribution required a flow coefficient C_Q of 0.00605 at the new stall speed which was 28 m.p.h. At this air speed, an airplane lift coefficient of 3.98 was developed. The air horsepower required for suction, the amplification factors, and the lift increments for all three distributions are shown in Fig. 2.

An investigation of the behavior of the aircraft during the stall, as well as boundary-layer profiles measured near the stall speed of 28 m.p.h., indicated that the stall of the airplane resulted from a laminar separation near the leading edge of the wing rather than from a turbulent separation from the rear.

This situation has been recognized as the limiting factor on high lift on the sailplanes. It was found that if turbulent separation is delayed long enough, laminar separation almost inevitably results as the angle of attack of the aircraft is increased. Therefore, no further efforts were made to influence the turbulent boundary layer. A new program was begun for the purpose of studying the laminar separation problem on the L-21.

Evaluation of Results

Both from previous experiments on the sailplanes and from the present work on the L-21 it appears that amplification factors $\Delta C_L/C_Q$ of the order of 300 may be expected where suction through distributed perforations is employed to prevent turbulent boundary-layer separation. It should be emphasized that this will hold true only when the suction is distributed according to the demands of the boundary layer. Arbitrary suction distributions inevitably result in low lift increments for relatively great suction quantities.

The use of Prandtl's form of the momentum equation as an aid to calculating the distribution of the suction is effective, but the method is limited by the fact that a knowledge is necessary of the boundary-layer parameters after the application of suction. This presumes a knowledge of suction effects on such things as surface shear, momentum thickness, velocity gradients, etc. For ease of application, Eq. (1) may be reduced to

$$v_0 = 3.5\theta_i U' - 0.5\, C_f U \tag{2}$$

where

v_0 = local inflow velocity
θ_i = value of momentum thickness at start of suction
U' = local velocity gradient obtained from potential flow distribution
U = local velocity obtained from potential flow distribution
C_f = turbulent flat plate skin friction evaluated at local RN based on distance run and local velocity

In practice, local velocities and local velocity gradients may be obtained either from potential flow calculations or by electrorheological methods. The initial value of the momentum thickness θ_i may be computed by several methods, among which is that of Tani[12]

$$\theta^2/v = 0.44 U^{-6} \int_0^x U^5\, dx \tag{3}$$

where U is local velocity, and x is measured along the surface from the stagnation point.

In order that large amplification factors on the order of 300 be obtained, it is necessary that the suction be

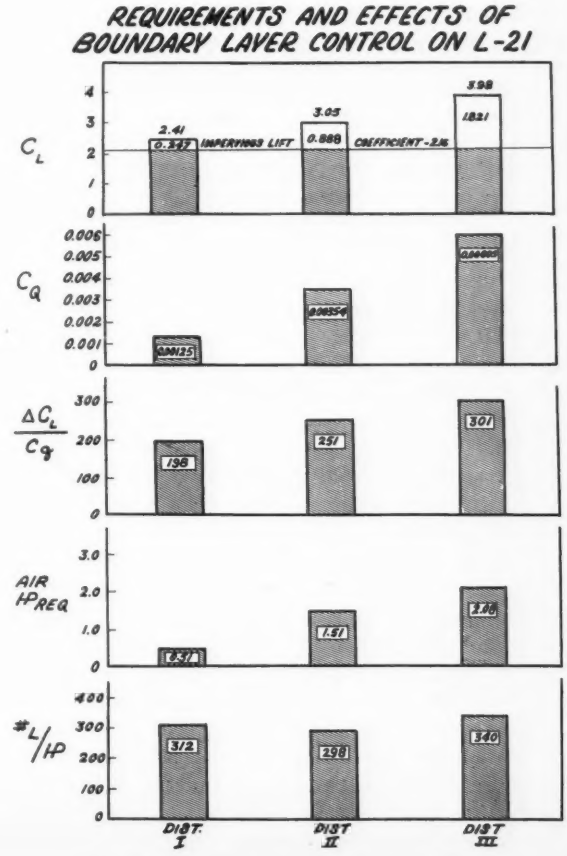

FIG. 2. Characteristics of L-21 suction system.

applied as near the point of transition as possible, surely no further aft than 25 per cent chord. It is assumed also that, for this method to be effective, the stall of the impervious wing must have resulted from a turbulent separation beginning at the trailing edge. This method has given a lift increment of 0.9 for an unflapped wing resulting in a maximum airplane lift coefficient of 2.30. The suction coefficient C_Q was 0.00316 and required less than one air horsepower for a sailplane having a gross weight of 1,300 lbs.[11]

Further Applications

It is believed that the use of suction through distributed perforations has applications not only to light planes but also to larger, transport-type aircraft. A study was performed for the Fairchild Engine and Airplane Company to evaluate the application of boundary-layer control by means of suction though distributed perforations on the C-119 Packet. The investigation was a cooperative undertaking wherein all velocity distributions and tuft photos, flight-test data, boundary-layer profiles, etc., were obtained in flight by the engineering staff of the Fairchild Aircraft Division. With this information, stalling characteristics of the airplane were evaluated and the necessary suction distributions were computed using the Prandtl form of the momentum equation.

Performance Measurements on L-21

The original purpose of the boundary-layer control sailplane was to test the concept of suction through distributed perforations. It has since become a demonstration vehicle with which to illustrate the behavior of boundary-layer control. With this sailplane it is possible to land without suction and, on touching down, apply suction and take off again. We can also show the effect of suction boundary-layer control applied to only one wing. A strong rolling moment is experienced.

However, the sailplane was unable to simulate the take-off of a powered airplane since it is towed off. For this reason, the L-21 Cub was next modified for boundary-layer control. Since the power required for suction was obtained by a belt from the propeller shaft, the final take-off measurements, when compared to a similar airplane, should show a shorter take-off over a 50-ft. obstacle if the boundary-layer control system is really effective.

Lacking an exactly similar L-21, the nearest equivalent—a Piper PA-18 with a 135-hp. engine—was used as the comparison airplane. For the comparison measurements the two airplanes were flown at gross weights such that the power loadings of the two airplanes were identical, $W/HP = 11.1$ (lbs./hp.).

For recording the take-offs, a multiple exposure camera was developed which yielded a complete recording of distance, altitude, and time. The flights were made early in the evening when the atmosphere was quite stable and turbulence-free. The pilots of both airplanes were thoroughly practiced on short take-offs in their respective aircraft. To reduce influence of technique, take-offs were made at a series of closely spaced take-off speeds.

Fig. 3 shows the take-off distances versus take-off speed. A 42 per cent reduction in take-off distance over 50 ft. is clearly shown for the boundary-layer control airplane when distributed suction boundary-layer control is used. It should be mentioned that ideally the two airplanes should have the same engines and should be compared experimentally at the same wing loading or even at the same pay load so that the additional weight of the boundary-layer control system (35 lbs.) and tricycle landing gear (45 lbs.) is considered.

In order to determine what flight parameters set the limit to the improvement in take-off obtainable with boundary-layer control, a series of performance measurements were made in gliding flight and with propulsion. In the gliding measurements, the thrust horsepower required for level flight with boundary-layer control was found (Fig. 4). These measurements were not made up to the maximum lift coefficient because steady-state flight could not be held close to the maximum lift coefficient. Included in this illustration are the two curves for a classical slotted flap without suction (unperforated). Comparison of the suction curves with these shows that the thrust horsepower is reduced by 3 hp. with the application of 2 hp. to the suction boundary-layer control. At higher speeds the saving is even greater. The rise in power required as the stall is approached is clearly seen in Fig. 5 where the climb-out angle is plotted as a function of air speed. It is clearly evident that the maximum climb-out angle is obtained with a flap setting of 1/3 of full-flap angle of an air speed of 48 m.p.h. Even more striking is the loss of climb-out angle as the air speed is decreased below 48 m.p.h. This behavior clearly illustrates the need for higher efficiency in the propulsive system at the lower speeds. In other words, although the airplane is able to get off the ground in a shorter distance with boundary-layer control, it cannot climb out steeply at minimum take-off speed.

Fig. 6 shows the linearized drag polars obtained in gliding flight with suction on. It will be seen that the slope of the curve with full flaps is steepest. In fact, the span efficiency factor computed for the full-flap curve comes out to be 107 per cent. This means that some thrust is being developed by the suction air passing through the engine, being heated, and then exhausted at a speed in excess of flight speed.

Table 1 summarizes results of tests to determine the maximum lift coefficient obtainable under controlled

Table 1

Flap Setting	PA-18 No Boundary-Layer Control		Army L-21 Boundary-Layer Control	
	Power-Off	Power-On	Power-Off	Power-On
0	1.3	1.6	2.6	2.5
1/3			2.8	3.2
1/2	1.4	2.0	2.8	3.0
Full	1.55	2.16	3.0	4.0

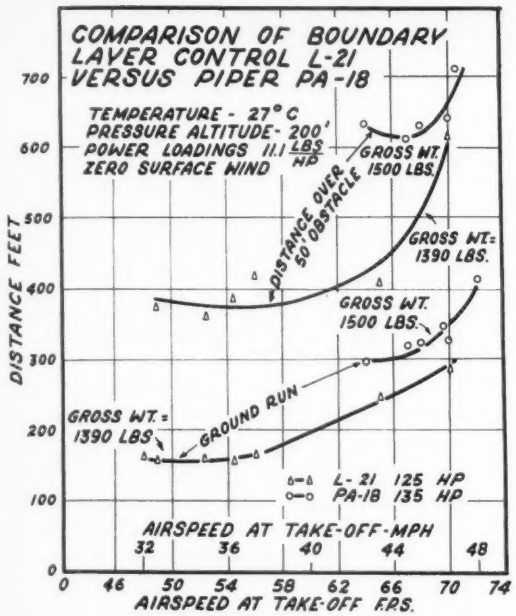

FIG. 3. Comparison of Super Cub and L-21 with boundary-layer control.

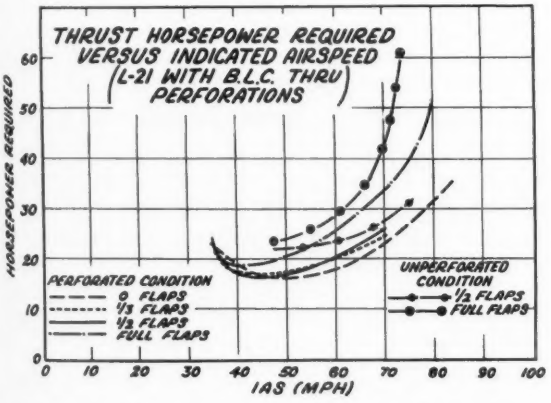

FIG. 4. Thrust horsepower requirements of L-21 with boundary-layer control.

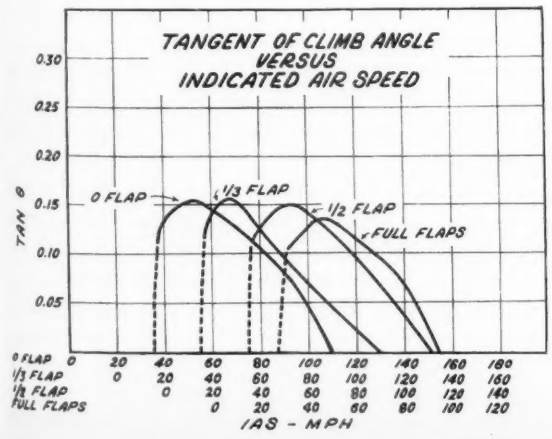

FIG. 5. Climb angle of L-21 versus indicated air speed.

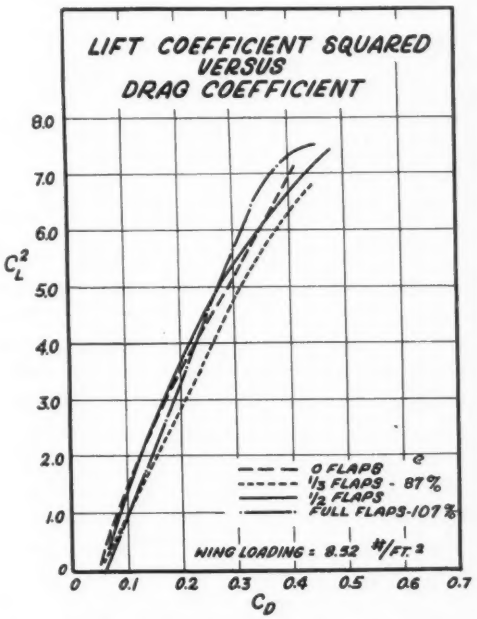

FIG. 6. Linearized polar of L-21 with boundary-layer control.

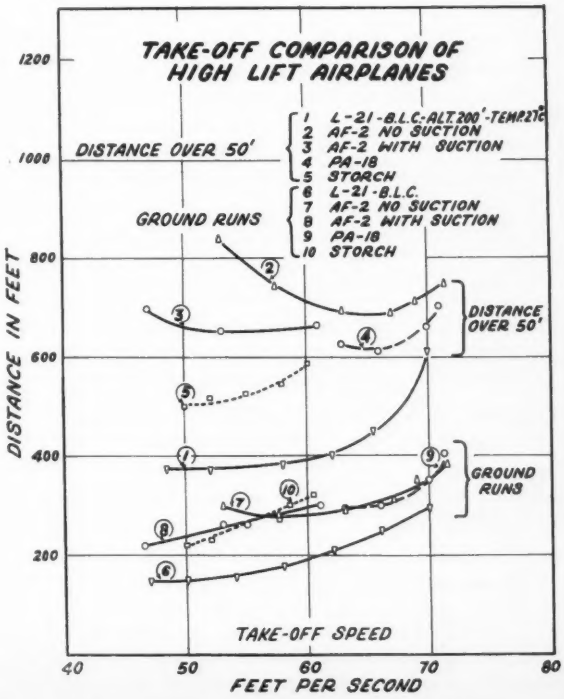

FIG. 7. Take-off comparison of high lift airplanes.

full power-on flight. From this table, one sees that the increment in maximum lift coefficient between power-on and power-off for suction with full-flap deflection is 1.0, whereas without suction the increment is 0.6. In other words, the flap combined with suction turns the slipstream of the propeller so as to gain additional lift. This is in essence what is desired for vertical take-off fixed-wing airplanes using the power of the slipstream for lift. The effectiveness of distributed suction with a flap for deflecting the slipstream downward should be compared with the classical method of using a leading-edge slot with multiple flaps. In particular, the power required to affect the turning introduced should be weighed against the loss in propulsion which reduces the climb-out angle so seriously on the L-21.

Stability and Control of L-21 with Distributed Perforation BLC

Flight tests on the sailplane showed that, when boundary-layer control through distributed perforations is applied to the sailplane, the pitching moments cause a nose-up pitch. This takes place because the pressure peak at the forward part of the airfoil is most effective in producing lift. Because the lift is so developed, no large increment in lift is lost as a result of down load on the horizontal tail.

The foregoing results were confirmed on the L-21. It was found that no modification to the horizontal tail was needed to trim the boundary-layer control airfoil to lift coefficients as high as 4.0 (power-on).

From the sailplane studies, it was also found that lateral stability and control was well retained up to the stall. In fact, on the sailplane the lateral stability in the stall was adjusted to a satisfactory state by modifying suction distribution as needed in the tip region.

Since the momentum in the boundary-layer flow over the ailerons is increased by suction, it is to be expected that lateral control would be satisfactory at the higher lift coefficients obtainable by boundary-layer control. This was confirmed by both the L-21 Cub and the sailplane flight tests.

On the L-21 the directional control is marginal when taking off at the lowest speeds possible with boundary-layer control. The engine torque and slipstream cause a large yawing moment which, at the slower speeds, the standard L-21 rudder is just barely able to overcome. Also, a loss of directional stability resulted from the addition of the front wheel of the tricycle gear to the L-21. However, the L-21 possesses sufficient directional stability and control so that it can take off and land at the slowest speeds useful for short take-off by amateur pilots.

Comparison of the BLC Airplanes AF-2 and the L-21

An interesting comparison of a single suction slot boundary-layer control system applied to a small airplane is that of the AF-2 versus the Fi-156 (Fieseler Storch). The characteristics of these airplanes are shown in Table 2.

Table 2

	AF-2	Fi-156
Span, ft.	51.5	48.2
Wing area, sq.ft.	259	279
AR	9.65	7.8
Weight empty, lbs.	2,450	2,150
Flight weight, lbs.	2,940	2,770
Wing loading	11.35	9.94
Horsepower	270	240
Power loading, lbs./hp.	10.9	11.52
Inner flap chord, %C	19	25
Outer flap chord, %C	25	...
Area flap, ft.^{2}	31.4	23.6
Propeller diameter, ft.	8.52	8.52
Prop pitch, ft.	Variable	4.68
Suction power, hp.	45	0

Since both of these airplanes were accurately flight tested for take-off performance—the AF-2 by Stüper and the Fi-156 by Hoerner[13]—a rational conclusion on the efficiency of a single suction slot located at the flap and aileron hinge line can be drawn from this work. Fig. 7 shows the ground run and the distance over 50 ft. for these airplanes plotted against take-off speed. It will be seen that, while suction does reduce the distance over 50 ft. of the AF-2 when compared to the same airplane with boundary-layer control off, no such advantage can be claimed for the AF-2 when compared to the Fi-156 Storch. In fact, the Storch gets over 50 ft. in 77 per cent of the distance of the AF-2.

The AF-2 takes its suction power (about 45 hp.) directly from the engine through shafting. The Storch, on the other hand, uses slots and flaps to achieve high lift coefficients. The comparison in Fig. 7 clearly shows that the 45 hp. used for suction on the AF-2 was not employed so effectively as the same power put into the propeller of the Storch. Fundamentally then, single slot suction requires more power to achieve high lift coefficients than does the slot-flap scheme.

Since the ground runs of the AF-2 and the Storch are nearly equal over a considerable range of take-off speeds, one sees that the AF-2 suffers a loss over the Storch on the climb-out or the so-called air path and transition. The suction power, therefore, detracted from the power available for climb.

On Fig. 7 are also plotted the results from tests on the take-off of the L-21 versus the PA-18. In this case, the slotted flap on the PA-18 was shown to be less efficient than the distributed perforation boundary-layer system on the L-21.

The L-21 shows a ground run of nearly one half that of the PA-18. However, since the L-21 also suffers a loss in climb-out angle, the take-off over 50 ft. does not show so great a reduction as does the ground run.

The comparisons of the two pairs of nearly identical airplanes—AF-2 versus Storch and the L-21 versus PA-18—illustrate the importance of low power requirement in designing boundary-layer control systems. Even where auxiliary sources of power are available, the lower power requirements mean a lighter system.

Safety Consideration for BLC Airplanes

If a pilot is to utilize the potential of a boundary-layer control airplane, he must feel secure in steep take-offs with the system absolutely reliable. Furthermore, he will exploit the potential all the more if he can glide to a slow speed landing should his engine fail. Since the L-21 uses a suction blower driven by the engine, should a power failure occur, both propulsion and boundary-layer control are lost. For this reason, there exists with this airplane a zone of altitude in which the pilot cannot pick up the additional flying speed needed to fly without boundary-layer control. Therefore, the full potential of boundary-layer control cannot be exploited with a system deriving power for suction from the main power plant. Ideally, the boundary-layer control suction power requirements should be kept low enough so that a storage battery of nominal weight can provide suction power for at least a minute or so.

Other power schemes may also be used. However, the storage battery is ideal for small airplanes since it can be used for boundary-layer control during the landing. The boundary-layer control can be turned off or on at will to effect a short landing when storage battery power is used. On larger airplanes, an auxiliary power source can be used.

Practical Considerations of Producing Perforated Surfaces

On the sailplane the plywood leading edge was perforated by hand drilling. Some 600,000 holes were so drilled at the rate of about 1 per sec. However, the fabric portion of the wing was pecked at the rate of 10 holes per sec. with an automatic pricking device.

Recently an automatic air-turbine-driven drilling machine has been developed in this laboratory which spaces the holes 10 per in. and drills them at the rate of 5.2 per sec. in 0.032-in. aluminum. This machine has an air pressure control of the drill so that optimum drilling speed is attained by the drill rotating at 60,000 r.p.m. With such a device, the apparently impossible task of drilling the order of millions of holes no longer appears impossible. This machine has in fact drilled chrome-moly alloy at the rate of 2 holes per sec.

Structural problems of stress and fatigue have been studied by Cliett.[14] Further studies are needed to examine other materials and means to reduce the fatigue losses in the rows of perforations.

Conclusion

From the studies of boundary-layer control by suction through distributed perforations, the following conclusions can be drawn:

(1) Considerable savings in suction power requirements can be realized by using distributed suction in contrast to single slot systems.

(2) Distributed suction for stall control imposes no severe trim requirements.

(3) Lateral stability in the stall may be controlled by altering suction distribution near the tips.

(4) While an improvement in take-off over the obstacle is achieved when distributed suction is used, the full potential of the technique cannot be realized until the propulsive efficiency at low speeds is improved.

(5) The technique of distributing suction by means of the momentum equation of the boundary layer does yield a suction airfoil with a stall delay using suction powers of much smaller values than single slot systems.

(6) The results obtained in this work may be generalized to any problem of flow control in the turbulent boundary layer in an adverse pressure gradient.

(7) The task of drilling perforated surfaces having spacing can be made automatic and fast even with small drills.

(8) During 18 months of flying, the L-21 required no attention to the perforated cloth surface because of clogging. It was restored before this period after having been rained on in a dusty condition. Restoration consisted of vacuum cleaner brushing.

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[14] Cliett, Charles B., *Structural Comparison of Perforated Skin Surfaces with Other Means of Effecting Boundary-Layer Control by Suction*, Aeronautical Engineering Review, Vol. 12, No. 9, pp. 46–54, September, 1953.

The turboprop makes possible cargo transport operation from short airfields through its ability to give short take-off distances and high angles of climb and descent. With lower gross weights to do a given job, a smaller number of engines required, and good fuel savings, it is also an exceptionally economical vehicle. Therefore, the author suggests that the turboprop can provide the nation with the maximum cargo transport capability for each dollar expended.

The Turbine-Propeller Combination in the Air Force

Lt. Col. Roy J. Wellman

Directorate of Research and Development, Headquarters,* USAF

Introduction

In spite of the fact that we have transport aircraft which cruise at nearly 350 m.p.h., the movement of large quantities of goods on a global basis from producer to consumer is still accomplished at an average speed little better than that of the covered wagon.

To improve the economy and flexibility of a cargo transport system aircraft with long nonstop ranges and with ability to get into and out of a maximum number of airfields all over the globe is a necessity. The ability to use a larger number of airfields increases flexibility and mobility by making the system more responsive to sudden changes in operational demands. It reduces the reaction time to adapt the supporting logistics to a new operation.

Just as the dispersal of manufacturing plants reduces the vulnerability of an industry to enemy attack, so the dispersal of supply points reduces the vulnerability of a supporting logistic transport system. The number of airfields available in a given area determines how easily and to what degree dispersal can be accomplished and how quickly the shift in supply points can be made.

As an example, reducing the take-off distance by one half, from 8,000 to 4,000 ft., will increase the number of airfields available in the continental United States by a factor of nearly six, or to 600 airfields. Reducing take-off distance once again by one half, from 4,000 to 2,000 ft., would make available three times as many airfields as would be available to an airplane requiring 4,000 ft. for take-off.

The factors which determine the distance required to clear a 50-ft. obstacle for a fixed-wing aircraft are wing loading, thrust loading, lift coefficient, and air density.

Fig. 1 illustrates the important parameters for reducing the take-off run.[1] This figure shows that the distance required to clear a 50-ft. obstacle is inversely proportional to the thrust available. Thus doubling the thrust available will reduce by one half the required take-off distance.

Thrust Available and Required for an Airplane

The thrust required for a design cruising speed is approximately the same for a given airplane whether powered with turboprops or turbojets. The characteristics of a propeller provide an increasing amount of thrust with decreasing aircraft velocity. The characteristic variation of thrust from a turbine-driven propeller and from a turbojet engine, both designed to produce the same thrust at the design cruise speed, may be illustrated readily. At any velocity lower than the design cruising speed, the difference between thrust available and thrust required represents the thrust usable for climb or acceleration, and this extra margin of thrust shortens take-off roll. As a result of the propeller characteristics, the turboprop will have two to three times the thrust of the turbojet available for take-off, where both have the same air handling capacity through the engine. It is seen that the turbine-propeller combination is admirably suited to meeting the need for shorter take-off and landing distances.

Angles of Climb and Glide

The greater thrust available from the propeller up to the design velocity enables a greater angle of climb to be maintained after take-off. This is advantageous in making use of the maximum number of airfields because obstructions can be cleared in less ground distance, and those areas affected by noise can be reduced.

During approaches to a landing area, the ability to make a steep approach determines which airfields are available for practical use. Here again, the propeller can provide ample glide path control by bringing the

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* Western Development Division.

propeller into lower pitch during the approaches. In effect, the propeller serves the combined function of assisted take-off and effective glide path control without need of JATO or parachute.

Direct Operating Costs Comparison

Fig. 2 shows a direct operating cost index per ton-mile comparison between turbojet and turboprop transport aircraft designed for operation from 4,500 ft. of runway.[1] One point representing minimum cost for a reciprocating engine transport, using a field length of 4,500 ft. and designed for 3,500 nautical mile range, has been included for comparison. This graph shows several interesting trends. First, for aircraft designed for equal costs per ton nautical mile and for equal pay loads, the turboprop aircraft will be the faster aircraft. Also, this comparison shows that, for equal cruising speeds, the turboprop is the more economical. Only for the greatest differential in costs per ton-mile is there a speed differential in favor of the turbojet, and this all at lower gross weights for all the turboprop aircraft of the same pay load, range, and speed. Fig. 2 suggests that the limit of reduction of cost per ton-mile with increasing engine size has not been reached at 15,000-hp. per engine, nor at 15,000 lbs. of thrust per engine for four-engined aircraft. The possible use of turbine engines of higher horsepower than 15,000 is indicated by the economics of engine size shown in Fig. 2 and by the desire to have short take-off and landing distances. Further development of propellers and turbine engines will make increased efficiencies attainable.

Development Facilities

As a matter of practical interest, facilities for engines and propellers of this order of capacity are already in existence or in the planning stage. Test equipment capable of whirl-testing propellers up to 30,000 hp. is installed at the Wright Air Development Center. A turbine-engine dynamometer capable of handling 30,000 hp. is on contract for installation in the engine test facility at the Arnold Engineering Development Center in Tennessee.

Experience

The Air Force has six turboprop aircraft being operated by the Military Air Transport Service on scheduled routes between several MATS bases with the object of obtaining operational experience. The first two aircraft are Convair YC-131C's powered with the 3,250-hp. Allison YT56 turbine engines and Aeroproducts propellers. As of December 15, 1955, these aircraft had flown 3,020 hours since May 1, 1954, averaging over 200 hours per month per aircraft, at a total cost of $108.93 per flying hour.

Two Boeing YC-97J aircraft are now in service with MATS. These aircraft are powered with the Pratt & Whitney T34 engines rated at 6,000 effective s.hp. and equipped with Curtiss propellers. As of December 15, the YC-97J's had 500 total flying hours.

Two Lockheed C-121F aircraft are about to start their test program with MATS. The C-121F'2 are powered with the T34 turbines and Hamilton Standard propellers.

In addition, the Air Force has installed T34 engines with Curtiss propellers in one C-124B aircraft to obtain engineering design information for future turboprop transports. Experience to date with these aircraft has been highly encouraging.

The Potential of the Turbine Engine

Fig. 3 shows the potential of the isolated turbine-propeller combination where higher turbine inlet temperatures are used.[2] The cross-hatched vertical area represents the range of current turbine temperatures. The effects of compressor ratio and turbine temperatures are shown for both turbojet and turboprop engine types. The divergence of the specific fuel consumption curves of the turboprops and turbojets with increasing temperatures is evident. What now is a 30 per cent difference between turbojet and turboprop specific fuel consumption will become greater with increasing turbine inlet temperatures.

The turbine inlet temperatures in use today are already past the point where increasing turbine temperatures will improve the specific fuel consumption of a turbojet. However, both the specific thrust and the specific fuel consumption of a turboprop can still be improved by increase in turbine inlet temperatures. Specific fuel consumptions are obtainable which are less than that of the best reciprocating engines.[3] The tremendous effort that has been expended in the component development of the turbojet engine can benefit the turboprop. Additional improvements such as turbine blade cooling to allow higher turbine temperatures can further improve the turboprop. The turboprop type of engine is more sensitive than the turbojet to further improvement in component compressor and turbine efficiencies.

Turboprop power plant plus propeller weight is about $2^1/_2$ times that of the comparable turbojet engine of the same mass airflow through the engine. This is the result of applying most of the developments and weight-savings, such as strategic material content, to combat jet engines. These were not applied to the turboprop engine because of a higher priority placed on combat jet engines. Considerable weight-saving is still obtainable in the turboprop engine and propeller. However, even at the present state-of-the-art as measured by specific fuel consumption and power-plant weights, all of the turboprop aircraft shown in Fig. 4 are of a lower gross weight than any of the comparable aircraft.

The Potential of the Propeller

The propeller used with the gas turbine serves as a thrust augmenter by making possible the mechanical separation of the mass of air used for propulsion from

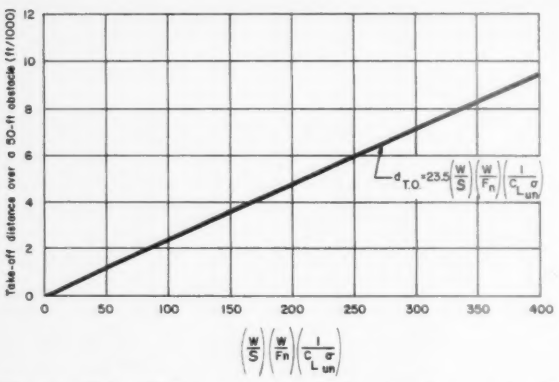

FIG. 1. Take-off distance over a 50-ft. obstacle vs. take-off distance parameter.

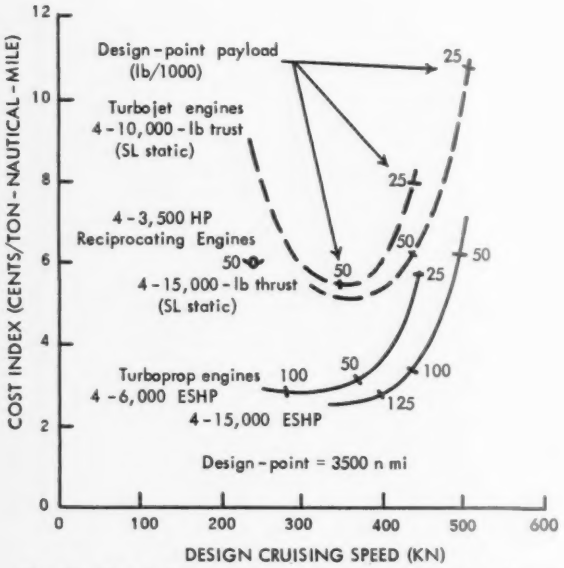

FIG. 2. Cost index vs. design cruising speed for two sizes of turboprop engines and two sizes of turbojet engines. Reciprocating engine point from Fig. 1.

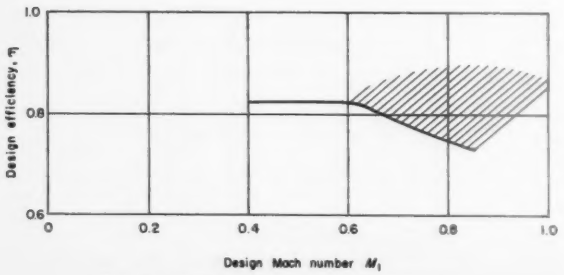

FIG. 5. Propeller aerodynamic properties.

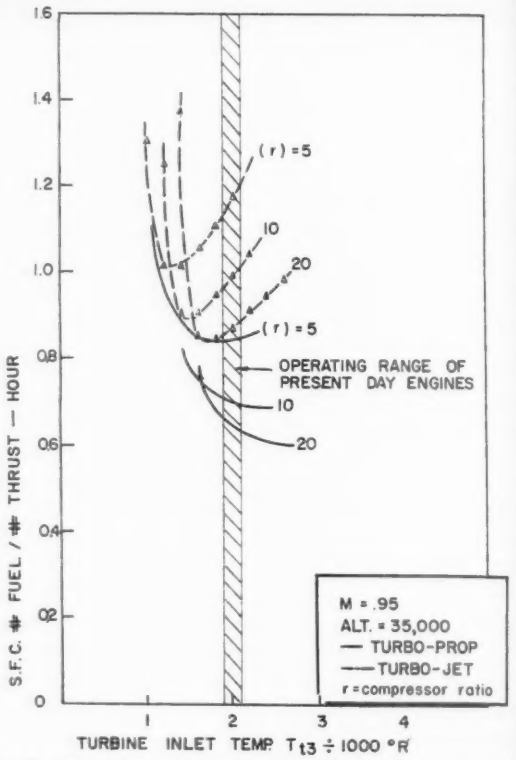

FIG. 3. Relative specific fuel consumption (S.F.C.) vs. turbine inlet temperature (T_{ta}) of the turboprop and the turbojet.

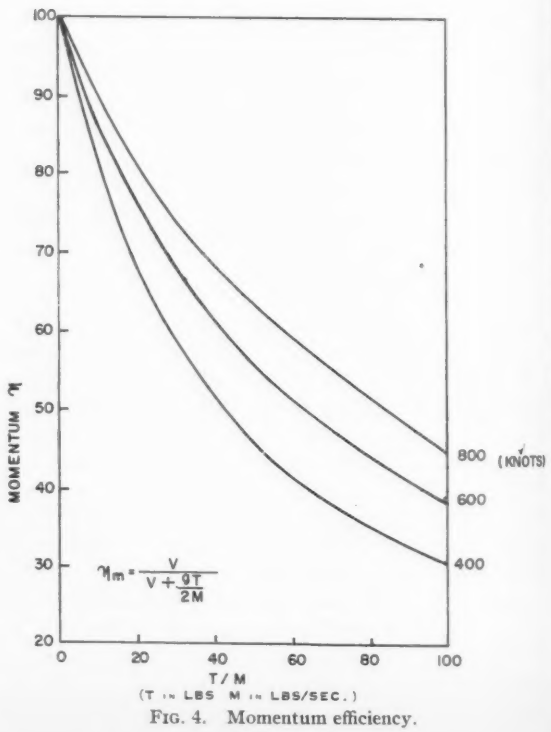

FIG. 4. Momentum efficiency.

the mass of air processed through the engine. It is this ability to use a larger mass of air for propulsion which makes possible high momentum efficiencies. Fig. 4 shows the variation of the momentum efficiency with the thrust per pound of air per second used for propulsion. This variation is the result of the fact that it is more efficient to accelerate a larger mass of air through a small acceleration than to accelerate a small mass through a large acceleration because of the higher kinetic energy differences involved with large changes between inlet and outlet velocities.[4]

How nearly these ideal momentum efficiencies can be obtained is determined by how high a lift-to-drag ratio can be maintained upon the propeller blade. In general, the propeller blade is a wing flying in a helical path. The factors that improve the L/D of a wing will improve the L/D of the propeller section also. Since there are centrifugal forces which help provide stiffness to a propeller blade, considerably thinner airfoil sections can be used for propeller blades than for a wing of the same aspect ratio and load per unit wing area.

In the area of propeller structures, materials, and fabrication, development work is pointed at reducing specific propeller weights for a given design condition.

Improvements in propeller aerodynamics and structures which are now in the flight-test stage will, when applied to future aircraft, enable raising the propeller efficiency curve on the high-speed end from what is shown in Fig. 5 and upon which the performance in Fig. 2 was based.[1] The result of this on turboprop aircraft performance would be to shift the present crossover point (from that indicated in Fig. 2 as approximately 520 knots) to a higher speed.

The results of much aerodynamic research have scrapped the concept that a propeller is limited to 900 ft. per sec. tip speed in order to obtain good efficiency. As a result, more nearly optimum blade angles can be maintained with higher forward velocities. In this effort, much theoretical and wind-tunnel work has been done, and flight tests are going on to broaden the accepted usefulness of the propeller.

Flight Tests

For flight testing, the NACA is operating a McDonnell XF-88B aircraft having an Allison T38 engine mounted in the nose in addition to its original jet engines. This vehicle can test propellers in free flight in the high-speed regime and is instrumented to determine their characteristics. The Air Force is operating two Republic XF-84H aircraft which are powered now with Allison T40 engines but will have the later T54 engines when available. Supersonic-type propellers by Aeroproducts, Hamilton Standard, and Curtiss will be tested.

The Air Force has also modified two Boeing B-47's by installing two Wright T49 turboprop engines with Curtiss propellers in place of the four inboard J47 engines. The first XB-47D flew in August, 1955.

Noise Reduction

It has been experimentally determined that the propeller acoustical power level increases less rapidly with increasing horsepower per blade and with increasing tip speed.[5] This offers an indication that reducing the noise per pound of thrust produced is a possibility for large turboprop engines. Noise from the gas producer is a subject of fundamental investigation common to both turbojet and turboprop power plants, but the most immediate solution to the relief of noise for communities located adjacent to airports is for aircraft to climb out covering the shortest possible distance close to the ground.

Broad Problem

Today all the turboprop engines which are available in an advanced state-of-the-art as measured by specific fuel consumption are being utilized commercially or militarily. The big problem involved in turboprop development is concentrating enough effort to achieve a new turboprop engine and propeller in the same time period as a combat-type engine. Because of the difference in priorities, there results an artificially created difference in the state-of-the-art between the two types of engine at any one time.

The ideal turboprop engine should be designed from the beginning as a turboprop engine for logistic aircraft and scheduled to become operational at the same time as a combat engine. This would make available the latest turboprop state-of-the-art in the same time period for application to a logistic support system.

Another possible solution might be a free turbine type of turboprop which utilizes a production turbojet engine as its gas producer. The propeller, its power turbine shaft, and offset duct would then become a separate thrust augmenter to which the turbojet is attached. The manufacturing, supply, and repair of the turbojet would be the same as the combat engine. The advantage in cost, time, and availability of being able to tap large turbojet production lines for the gas producer is considerable. This approach might incur weight and/or frontal area penalties but illustrates one approach to solving the engine availability problem.

Conclusion

These various flight-test projects are being carried out to explore and exploit the technological potential of this nation to be sure it is getting superior equipment to meet the demands of an advanced logistic support system. Future cargo transports such as the C-130, C-133, and C-132 aircraft will be able to profit from the results of this research.

The turboprop transport is our only practical choice for improving our national civilian and military cargo transport system—from cost, speed, economy, flexibility, noise, and safety aspects. The net product is able to provide the global mobility essential to our needs.

(*Continued on page 61*)

VTOL-STOL Aircraft—Part II

Concluding papers, prepared for the IAS Annual Meeting in January, on vertical or slow rising and landing concepts. As in Part I of this series, editing and deletion of some illustrative material make possible this presentation over a much shorter period than if each was published in complete form in separate issues.—ED.

A Comparison Between Pay-Load Capabilities of VTOL and Conventional Aircraft

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Vertol Aircraft Corporation

INTRODUCTION

IT IS TRUE that the helicopter still remains the only operational VTOL aircraft and there is, as yet, no operational STOL aircraft (in the modern sense). But theoretical speculations and actual design studies of a great variety of basic concepts and types, belonging to the VTOL and STOL categories, are progressing at an ever-increasing pace.

One question which must be of great interest to the future operators of this new aircraft is the price in the pay load which will be paid either for completely vertical or for short take-off and landing capabilities. Another problem, which will probably be of interest to the operators, is the extent to which the pay load of a VTOL aircraft can be improved should a running take-off be possible. Finally, in those cases when hovering or near hovering regimes of flight may be required for some length of time, it is of interest to know how the time spent in this particular regime of flight may affect the pay-load capabilities of the VTOL aircraft.

In this short study, an attempt is made to give at least some idea as to the order of magnitude of the price in pay load which may be paid for the VTOL capabilities by a medium-size transport aircraft (gross weight between 50,000 and 100,000 lbs.) operating in forward flight cruising speed at sea level equal to 150 and 300 m.p.h.

It should be added at this point that, since the whole study is based on nonclassified material (power-plant and structural weights, fuel consumption, etc.) and since, in addition, some simplifying and somewhat arbitrary assumptions were made (for instance, cruising at sea level, arbitrary values of lift coefficient in cruising, etc.), a definite element of conservatism has probably been injected here.

PAY LOAD FOR A GIVEN RANGE

It may be assumed that weight of some structural groups (fuselage, empennage, landing gear, etc.), as well as that of other specific items, remains fixed

* Chief of Research and Development.

The author wishes to express his indebtedness to J. Mallen for his invaluable assistance in the preparation of this study.

(W_{fix}) for a given design gross weight W. In other words, it may be said that the W_{fix}/W ratio is a constant for a given gross weight. Under this assumption the pay load to gross weight ratio PL/W for any flight range may be considered as a function of such variables as relative weight of the lifting and propelling systems (W_{L+P}/W) and fuel required for cruising $(W_F/W)_{cr}$, plus associated tankage. For aircraft capable of hovering, an additional term expressing the weight ratio of fuel used in this regime of flight $(W_F/W)_h$ should also be considered. Under these assumptions, the pay load to gross weight ratio can be expressed as follows:

$$\frac{PL}{GW} = 1 - \left[\frac{W_{fix}}{W} + \frac{W_{L+P}}{W} + \left(\frac{W_F}{W}\right)_h + \left(\frac{W_F}{W}\right)_{cr}\right] \quad (1)$$

where symbols not defined as yet are

PL = pay load
$GW \equiv W$ = gross weight

A glance at Eq. (1) will clearly indicate that the pay load to gross weight ratio for a given range will be made a maximum when the expression in the square brackets becomes a minimum. However, in order to perform this optimization of the PL/GW ratio, additional assumptions regarding such design parameters as engine specific weight, s.f.c., etc., must be made, just as such operational conditions as flying speed and altitude must be chosen.

Optimum Turboprop-Driven Aircraft

In order to establish the pay load to gross weight trends for conventional fixed-wing turboprop-driven aircraft, some assumptions have been made which are summarized in Table 1. In addition, it was necessary to select a formula for the wing weight W_W.

In this particular study, a formula based on reference 1 was used which expresses the wing weight in terms of its span b and its area S. Assuming design load factor of 4.5, expressing wing span in feet and wing area in square feet, and allowing 9 per cent for the weight of ailerons and flaps, the equation of reference 1 can be rewritten as follows:

$$W_W = 1.09\ W^{1/4}S^{3/4} + 4.6 \times 10^{-5}\ W(b^3/S) \quad (2)$$

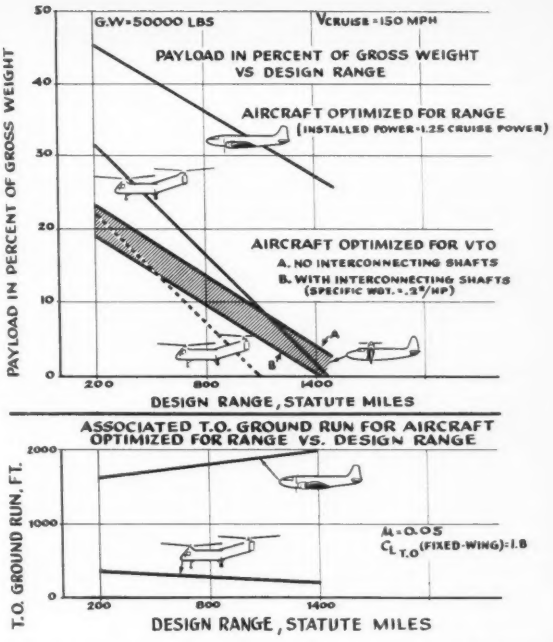

FIG. 1. Effect of VTOL capabilities on pay load of aircraft designed for 150 m.p.h. cruise.

Making use of the assumptions listed in Table 1, standard formulas for power required in forward flight, as well as Eq. (2), all weight ratios appearing within the square brackets of Eq. (1) can be expressed for any chosen range value* as a function of the span b considered as an independent variable.

Now it was possible to find the wing span which yields the optimum pay load/gross weight ratio for any given range value. The results of this operation are shown in Figs. 1 and 2 as optimum pay load to gross weight ratios vs. range. Fig. 1 refers to the 50,000-lb. aircraft cruising at 150 m.p.h., while Fig. 2 refers to an aircraft of the same gross weight cruising at 300 m.p.h. The results for the 100,000-lb. aircraft are almost identical as far as the slope of the (PL/GW) vs. range curve

* In this study, ranges of 200, 800, and 1,400 miles were considered.

TABLE 1
Assumptions for Determining Optimum PL/GW Ratio of Fixed- and Rotary-Wing Aircraft

Aircraft	Fixed Wing				Helicopter
V_{cr}, m.p.h.	150		300		150
Cruising altitude	s.l.	s.l.	s.l.	s.l.	s.l.
Gross weight W, lbs.	50,000	100,000	50,000	100,000	50,000
W_{fix}/W, %	35	30	36	31	30
s.f.c., lbs./hp.-hr.	0.63	0.63	0.63	0.63	0.63
Weight of fuel system, lbs./gal.	0.25	0.25	0.25	0.25	0.45
Installed horsepower, $(BHP)_{cr}$	1.25	1.25	1.25	1.25	1.25
Specific weight of power-plant installation, lbs./BHP	0.505	0.505	0.505	0.505	0.55
Specific weight of shafting, lbs./BHP	0	0	0	0	0.9
Number of propellers or rotors	2	4	2	4	2
Specific weight of propeller group, lbs./BHP	0.3	0.3	0.3	0.3	...
Propeller efficiency in cruise, %	80	80	80	80	...
Equivalent flat-plate area, sq.ft.	17	33	17	33	25
C_L at cruise or $\overline{C_L}$ in hovering	0.4	0.4	0.4	0.4	0.5

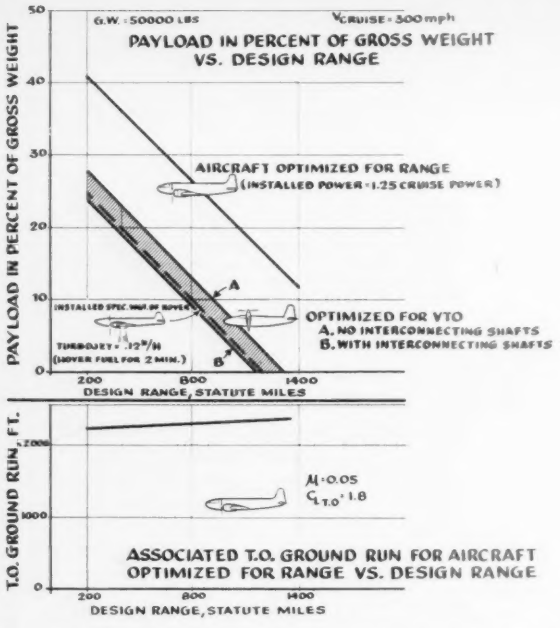
G.W. = 50000 LBS
V CRUISE = 300 mph
PAYLOAD IN PERCENT OF GROSS WEIGHT
VS. DESIGN RANGE
PAYLOAD IN PERCENT OF GROSS WEIGHT
AIRCRAFT OPTIMIZED FOR RANGE
(INSTALLED POWER = 1.25 CRUISE POWER)
A
OPTIMIZED FOR VTO
A. NO INTERCONNECTING SHAFTS
B. WITH INTERCONNECTING SHAFTS
B
TURBOJET = .12 #/H
(HOVER FUEL FOR 2 MIN.)
DESIGN RANGE, STATUTE MILES
T.O. GROUND RUN, FT.
μ = 0.05
C L T.O. = 1.8
ASSOCIATED T.O. GROUND RUN FOR AIRCRAFT
OPTIMIZED FOR RANGE VS. DESIGN RANGE
DESIGN RANGE, STATUTE MILES

FIG. 2. Effect of VTOL capabilities on pay load of aircraft designed for 300 m.p.h. cruise.

is concerned, except that the whole curves are displaced upward by a few per cent.*

As expected, the take-off ground run of aircraft optimized for pay load is far from what can be called short. Rolling distances calculated for the take-off speed corresponding to $C_L = 1.8$ and friction coefficient $\mu = 0.05$ are shown at the bottom of Figs. 1 and 2.

In order to obtain a comparison with fixed-wing aircraft of a helicopter optimized for pay load, an appropriate study was made assuming a cruising speed of 150 m.p.h. and a gross weight of 50,000 lbs. The assumptions made for the helicopter, of tandem configuration, are listed in the last column of Table 1.

Selection of the average rotor lift coefficient in hovering at sea level, as well as its tip speed, defines immediately the numerical value of the total blade area per rotor ($\sigma\pi R^2$). This, in turn, permits a simplification of the expression for correlating the weight trends of existing helicopter rotors. This expression giving the weight of the helicopter rotor group W_R† is

$$W_R = 378[0.84\, HP\, R^3\sqrt{\sigma}/(V_t/R)\ 10^4]^{0.4} \quad (3)$$

or, when the $\sigma\pi R^2$ value is known, it may be rewritten as

$$W_R = 378\,[0.84\, HP\, R^2\sqrt{\sigma\pi R^2}/\sqrt{\pi}(V_t/R)\ 10^4]^{0.4} \quad (3a)$$

where HP represents the horsepower per rotor, and V_t is the tip speed.

Using values of various parameters as listed in Table 1, as well as taking into account Eq. (3a), it is possible to find rotor radius R which optimizes the helicopter PL/GW ratio for an assumed flight range. The results of this operation are shown in Fig. 1.

Since rotor radius has been optimized for the maximum pay load, it is not surprising to find that the helicopter designed around this criterion is underpowered as far as vertical flight performance is concerned and is unable to hover out of ground effect. Consequently, some actual ground run (or flight close to the ground) will be required before climb can be started. The required take-off runs are shown at the bottom of Fig. 1.

VTOL Aircraft

In order to evaluate the pay-load penalty encountered in VTOL aircraft, it is assumed that all aircraft previously designed for the optimum load carrying capacity are now provided with VTOL capabilities. It is assumed at first that the actual time in hovering is so short that it may be neglected. Under this assumption, the optimum solution (for the zero range condition) will be obtained for such combination of design parameters of the vertical thrust generating system which will yield a minimum weight of the system composed of the power plant, shafting, and actual vertical thrust generating devices (rotors, propellers, etc.).

In the case of the helicopter, solution to this optimization of the total vertical thrust generating system would consist of selecting a rotor radius which would assure that the sum of the weight of the rotor group, plus shafting, plus power plant would be a minimum. The optimization can easily be obtained for the assumptions previously made (Table 1), using the weight formula for the rotor as given by Eq. (3a) and the well-known expression for the power required in hovering out of ground effect.

Having optimized the engine-rotor system for hovering, the pay load vs. range for this helicopter is computed. The results are shown in Fig. 1 as a broken line. It can be seen that, even in the case of the helicopter, a pay-load penalty amounting to about 10 per cent of the gross weight is paid for VTOL capabilities.

As far as fixed-wing aircraft are concerned, there is a great variety of possible means for providing VTOL performance. From this array, attention will be concentrated on the tilting propeller-wing combination and special "short-life" turbojets. Selection of these two types has been dictated by the desire to bracket the study between a relatively lightly loaded vertical thrust generator at one extreme and that producing a high amount of thrust per square foot of jet exit area on the other.

Assuming that four propellers are installed on both 100,000- and 50,000-lb. gross weight airplanes, the propeller radii can be optimized to obtain a minimum weight of the propeller-plus-engine combination. In performing this process of optimization, an expression for the propeller weight similar to Eq. (3) was used:

$$W_{prop} = 748\,[0.84\, HP\, R^3\sqrt{\sigma}/(V_t/R)\ 10^4]^{0.3} \quad (4)$$

* Since curves referring to the 100,000-lb. aircraft would not contribute anything basically new, they are not shown.

† Developed by R. H. Swan of Vertol Aircraft Corporation.

In practice, it will probably be required that all propellers of VTOL aircraft be mechanically interconnected in order to eliminate lift asymmetry in the case of one-engine failure. This necessity of interconnecting shafting will obviously represent some penalty in pay-load capability. Assuming that the weight of interconnecting shafts is 0.2 lbs./HP, pay load vs. range of a tilt wing-propeller type of aircraft has been calculated and shown as lines B in Figs. 1 and 2.

It can be seen from Figs. 1 and 2 that, for the 150- and 300-m.p.h. cruising speed airplanes, the pay-load penalty associated with VTOL capabilities is quite high in general. It is, however, relatively greater for the slower airplane than for the faster. In order to complete the picture, pay-load vs. range characteristics of aircraft with no interconnecting shafting are also shown. It can be appreciated from Figs. 1 and 2 (lines A) that the elimination of interconnecting shafting will not significantly contribute to the improvement of the pay-load characteristics.

Pay-load vs. range capabilities of fixed-wing aircraft equipped with special turbojets for take-off and landing (specific installed weight 0.12 lbs./lb.) is shown in Fig. 2 as a dashed line. In computing the pay-load vs. range capabilities of this scheme an allowance of additional fuel for two-minute operation of these engines was incorporated. It can be seen from Fig. 2 that, for an extremely short time in hovering, the special turbojet scheme may become competitive with the tilt wing-propeller arrangement.

Since it may be expected that, from the point of view of structural weight, the deflected slipstream type of aircraft will not be much different from that of the tilting wing-propeller scheme, it may be assumed that the trends shown in Figs. 1 and 2 represent a rough approximation of pay-load penalties associated with the vertical take-off and landing characteristics of both tilting propeller-wing and deflected slipstream type.

Pay-Load Improvements of VTOL Aircraft with Running Take-Off

Having a VTOL aircraft of given pay-load capabilities, it may be of interest to know to what extent the load carrying capacity may improve when operational conditions permit a running take-off. Under these circumstances, the aircraft can be overloaded above its VTOL gross weight, and obviously the difference between the overload and the normal gross weight may represent an almost direct gain in pay load. Fig. 3 may give some indication as to the magnitude of these possible gains.

In the preparation of this figure, it was assumed that flow around the wing is not affected by the process of thrust generation. This means that total vertical force acting on the aircraft is simply obtained as an algebraic sum of lift produced by the wing (at a given forward speed and at a given angle of attack) and vertical component ($T_v = T \sin \theta$) of the total thrust developed by the thrust generator (see Fig. 3). Under the above assumptions, the wing would obviously remain throughout the whole ground run at an attitude similar to that of a conventional fixed-wing aircraft. As to the inclination of the thrust vector, it can easily be shown that the ground run will be a minimum when the thrust vector is inclined to the horizon at an angle θ defined as follows:

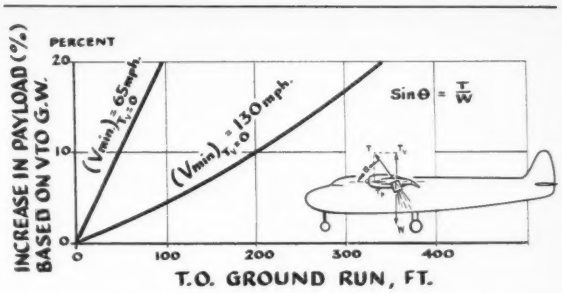

Fig. 3. Relative gains in pay load with running take-off.

$$\sin \theta = T/W \tag{5}$$

where T is the total thrust, and W is the gross weight.

In Fig. 3 gains in the gross weight vs. ground run were computed for two aircraft whose minimum flying speeds, with no vertical thrust component, are equal to 65 and 130 m.p.h. A glance at Fig. 3 clearly indicates that, for even a short take-off run, considerable gains in pay load may be realized. Fig. 3 also shows that these gains will be more spectacular for aircraft characterized by a lower minimum flying speed under the power-off condition.

Although some assumptions made in the preparation of Fig. 3 (for example, independence of the flow around the wing from the process of thrust generation, etc.) can be most closely approached in such configurations as fixed-wing aircraft equipped with tilting turbojets or ducted fans, it is believed that the trend of the gross weight gains vs. take-off run shown by this figure will be applicable to all VTOL aircraft.

Importance of Time in Hovering

Until now, no consideration was given to the time in hovering. However, this is an important factor that may influence the selection of the optimum design parameters of an aircraft. In Fig. 4 the amount of fuel required in 1 hour per lb. of vertical thrust is shown for various types of vertical thrust generator, ranging from conventional helicopters to turbojet engines. In order to correlate on a common basis relative fuel consumption of such a great variety of thrust generators, the jet exit area loading has been chosen as an independent variable.

The jet exit area loading is defined as the thrust divided by the cross section of the fully developed air stream associated with the generation of the thrust. It may be recalled at this point that, for the airscrew-type thrust generators, the ultimate jet area loading is

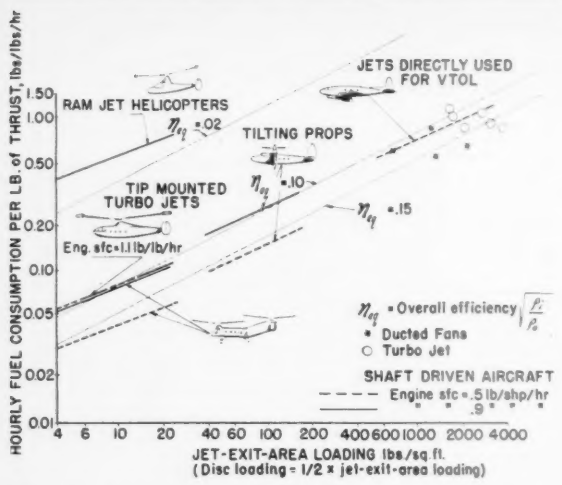

FIG. 4. Approximate hourly fuel flows per 1 lb. static thrust, shown as a function of jet exit area loading of various types of vertical thrust generator.

equal to twice the disc loading. This results from the assumption that in this case the cross-section area of the ultimate slipstream is equal to one half of the airscrew disc area. On the other hand, for such arrangements as ducted propellers and fans, as well as turbojet engines, the exit area of the duct—or exhaust pipe—may be considered as the "jet exit area."

In order to provide some feeling as to the efficiency with which thermochemical energy of fuel is used in the process of the vertical thrust generation, a few lines showing the equivalent efficiency η_{eq} are plotted in Fig. 4. This equivalent efficiency is defined as the product of the overall efficiency η_{o_v} and the square root of the ratio of the air density in the fully developed slipstream of the thrust generator ρ_j to the density of the ambient air ρ

$$\eta_{eq} = \eta_{o_v} \sqrt{\rho_j/\rho} \qquad (6)$$

The overall efficiency is defined, in turn, as the ratio of the ideal energy required per unit of time to generate a given thrust to that actually released from fuel.

It can be seen from Fig. 4 that for such fuels as gasoline and kerosene, with an approximate heat value of 19,500 B.t.u./lbs., the equivalent efficiency of about 15 per cent may be considered as representative for an extremely wide range of vertical thrust generators ranging from conventional helicopters to pure turbojets.

Even a superficial examination of Fig. 4 will give some intuitive feeling that, for those cases where long time in hovering is required, vertical thrust generation schemes based on low jet exit area loadings should be used.

However, in order to provide something more than an intuitive feeling with regard to the selection of a proper jet exit area loading for vertical thrust generators required to operate for various times in hovering, Fig. 5 has been prepared. Taking as an example the 50,000-lb. aircraft, a very approximate trend of relative weight of the vertical thrust generating system (actual thrust generator, plus shafting, plus engine) is shown starting with conventional helicopter and ending with special low-weight turbojets. The fuel required for various times in hovering based on the 15 per cent equivalent efficiency is also shown.

It is interesting to note the variation of the sum of the vertical thrust generating system weight and the fuel required for various times in hovering. It is obvious that the optimum solution for any given hovering time will be represented by those jet area loadings which would make the sum of the thrust generator and the fuel consumed a minimum. A glance at Fig. 5 would indicate that for long times in hovering, such as 1 hour and more, the jet exit area loadings corresponding to helicopter rotors are optimum. Then, as this time in hovering decreases, this optimum moves to the region of oversized propellers and later to ducted propellers and fans and finally comes to pure turbojets which may be attractive for a very short time in hovering.

CONCLUSIONS

This abbreviated study shows that the difference between pay load of a slow or medium-speed VTOL transport aircraft and that of a conventional fixed-wing airplane optimized for the load carrying capability may amount to 15 to 25 per cent of the gross weight. This is the pay-load penalty which must be paid for the introduction of a new degree of freedom.

It is the opinion of this author that, in order to obtain a full return for the price paid in pay load by the VTOL aircraft, it is imperative that the VTOL capabilities be realized in practical operation. Therefore, the true VTOL aircraft should have control characteristics, as well as safety provisions which would permit vertical take-offs and landings under all operational conditions.

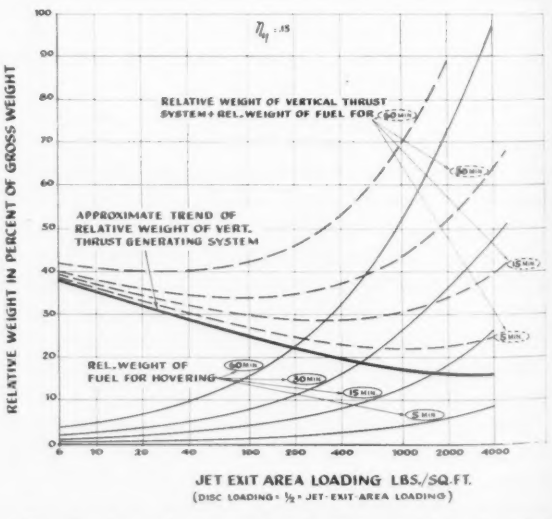

FIG. 5. Approximate trends of relative weights of vertical thrust generating system plus fuel required for various times in hovering.

The above requirement necessitates a true hovering aircraft.

It should be emphasized that pay-load capabilities of a true VTOL aircraft may be greatly improved when short running take-offs (and landings) are permitted.

Finally, it should be pointed out that time required in hovering is an important factor as far as design concept of a VTOL aircraft is concerned. For long times required in hovering, lightly loaded vertical thrust generators are most suitable, while, for extremely short hovering times, even concepts based on the turbojet principle may be advantageous.

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Propeller-Lifted Tilt-Wing VTOL Aircraft

Joseph Stuart III*
Hiller Helicopters

Introduction

Hiller Helicopters has long been interested in simpler, more efficient, higher performance vertical take-off aircraft types, including a jet-engine-lifted, delta-wing configuration, tested in model form in 1947, and a turbine-engine-powered ducted propeller type, on which a design study was undertaken. In addition, Hiller has been conducting a study of a retractable rotor system for the U.S. Air Force.

However, propeller-lifted, tilt-wing vertical take-off and landing Propelloplanes are the primary concern of this paper.

Contract Nonr-1657(00) was awarded by the Office of Naval Research for *A Propelloplane Transport Aircraft Study*. The ONR kindly permitted certain preliminary, appropriately modified information from this continuing study to be reported in this paper.

But before tilt-wing aircraft are considered in greater detail, it is first appropriate to compare important basic characteristics of several possible vertical lift generating systems.

A Comparison of Hovering Lift Generating Systems

Air-breathing devices that may be considered for high-performance VTOL aircraft vertical lift generation include lightweight, direct lifting turbojet or ducted fan engines; ducted propellers and fans powered by turbine engines; lifting propellers; lifting rotors, which may be idled, stopped, retracted, or tilted forward and used as propellers in high-speed forward flight; and slotted and flapped wings used to deflect propeller slipstreams.

Ducted propellers and fans will not be considered in detail because they tend to optimize toward lightweight turbojet or ducted fan engines. Similarly, the directed slipstream principle will not be further considered because it generates vertical lift less effectively than the tilt-wing configuration and because the elaborate slotted and flapped wing required to redirect the propeller slipstream is substantially heavier than the relatively normal tilt wing.

Fig. 1 presents the estimated characteristics of direct lifting, lightweight turbojets, turbine-engine-driven propellers, and turbine-engine-driven rotors as they might be applied to transport aircraft of approximately 60,000 lbs. gross weight: 33 small, 1,810 lbs. thrust turbojet engines would be used in a cluster; four eight-blade, dual-rotation propellers and two multiblade lifting rotors would be used on the tilt wing and tilt rotor machines, respectively.

In Fig. 1(A), the lifting rotors are shown to lift 9 lbs./b.hp., the propellers a little less than 4 lbs./b.hp., while turbojets are shown to lift but 0.8 of a pound per equivalent shaft b.hp. These lift per b.hp. values are reflected in the hovering-thrust specific fuel rates of these lifting systems, shown in Fig. 1(C). Propeller and rotor lifting systems obviously consume fuel at a

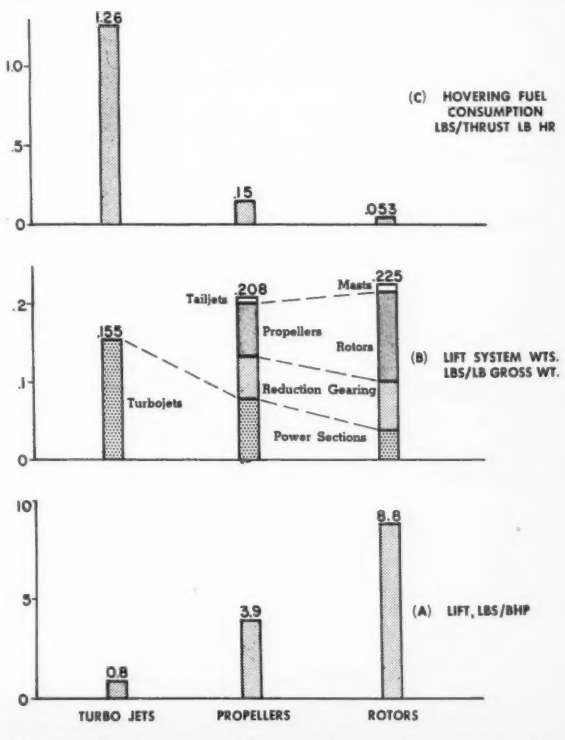

Fig. 1. VTOL transport aircraft, lifting system characteristics.

* Chief Technical Engineer.

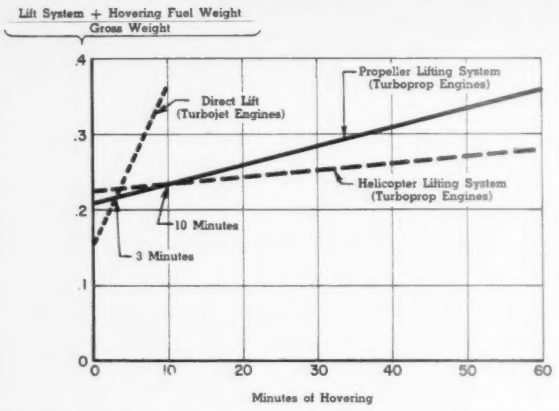

FIG. 2. Large (60,000-lb. gross weight) VTOL transport aircraft lifting system and fuel weight, ratios.

much lower rate under hovering conditions than do direct lift turbojet engines.

Fig. 1(B) shows the weight of machinery required to develop a pound of hovering lift. It is noteworthy that at this high gross weight the propellers are estimated to be lighter in weight than lifting rotors. (The weights of the tail jet engines needed to provide hovering pitching and yawing control, when propellers are used for hovering lift, have been included in the weight of the propeller lifting system.)

The lifting system weight information of Fig. 1(B) and the fuel consumption data of Fig. 1(C) are advantageously combined in Fig. 2 to give plots of the total weight of the lifting systems and the fuel they use in hovering, as a function of required hovering duration. (Engine-starting fuel allowances and reserve fuel weights are not included.)

Direct lifting turbojet engines are seen to be lightest for extremely short hovering durations of 3 min. or less. It is obvious, however, that VTOL aircraft using direct lifting turbojet engines will not be competitive in applications requiring substantial hovering times.

The propeller lifting system plus fuel weight is, in contrast, the lowest in the useful 3- to 10-min. hovering duration range and but little inferior to lifting rotors for required hovering durations of up to half an hour.

Compact propellers—with their long history of extensive service experience, well-developed manufacturing techniques, and freedom from the maintenance problems associated with flapping and drag hinges, etc.—thus immediately appear interesting for possible application to high-performance VTOL transport aircraft. The probable practicability of this technically interesting propeller application has, of course, been indicated by the actual flights made by the related Convair and Lockheed propeller-lifted VTOL, tilting fuselage fighters.

PROPELLER-WING INTERACTION

The probable practicability of propeller-lifted, tilt-wing VTOL Propelloplanes is also indicated by the results of theoretical analyses of propeller-wing interaction[1] and confirming NACA test results.[2, 3]

Fig. 3 presents a comparison of the theoretical required propeller thrust and wing resultant force values calculated using this approximate analytical approach and the corresponding NACA test values, both plotted as functions of the propeller shaft axis and wing zero lift line angle of attack. Agreement is surprisingly good.

A point of major importance is illustrated by the T/W required propeller thrust curve for the without-wing case. This curve shows how propeller thrust required would have to increase as the propeller axis was tilted forward from its 90° angle-of-attack, hovering position, if the vertical component of propeller thrust alone was required to carry the weight of the aircraft. This approximate theory indicates however (and the test data confirm) that, with the wing present, the required propeller thrust actually decreases as the propeller axis angle of attack is reduced from 90°.

Fig. 4 presents a similar comparison of calculated and measured trends of power required as a function of propeller shaft axis angle of attack. In this figure, general agreement that the power required at forward speeds higher than zero is always less than that required at hovering is indicated theoretically and again confirmed experimentally. The test data of reference 3 confirm that this conclusion would hold even if the propeller blade angles were excessively high and the propeller was being operated inefficiently overloaded and was largely stalled in hovering flight.

Theoretical studies thus indicate (and experimental tests of propellers—and of tilt-wing propeller combinations—at high angles of attack thus establish) that for tilt-wing Propelloplane in transition flight

(1) The propeller thrust required decreases as forward speed is gained

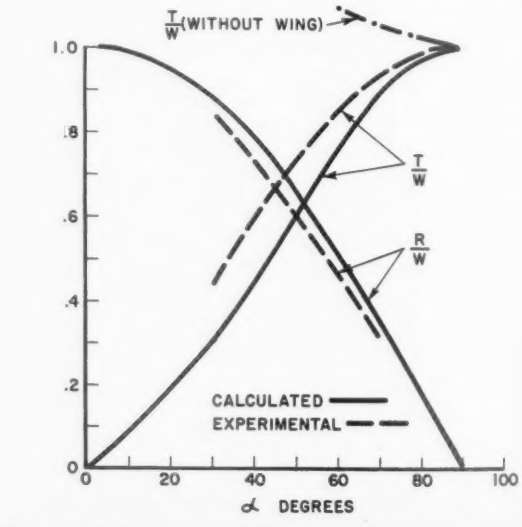

FIG. 3. Variation with angle of attack of required propeller thrust and wing resultant force.

(2) Propeller power required decreases as forward speed is gained

(3) The tilt-wing is not just an obstruction, "in the way" at high angles of attack. The tilt wing, on the contrary, actually contributes usefully to the lift of the wing-propeller system even at very high angles of attack approaching 90°.

Propeller Blade Stresses

Fig. 13 of reference 2, not reproduced herein, shows a maximum forward center of pressure shift of the propeller thrust of 20 per cent of the propeller radius, in translational flight of a wing-mounted propeller at high angles of attack. Resolution of this steady propeller shaft bending moment into equivalent 1P propeller blade shank section bending moments and their corresponding blade bending stress levels has indicated that the probable transition flight, vibratory stress levels will be acceptable. Strain-gage measurements support this conclusion.

A Possible Large Transport Propelloplane

Studies have shown a four-propeller, 60,000-lb. gross weight, ramp loaded, tilt-wing, Propelloplane transport to be possible. The necessary wing pivots must, of course, safely carry the entire weight of the aircraft. But this imposes no unusual or difficult engineering requirements. These loads are actually much lower than those carried, for example, by the main propeller blade retention bearings. From an engineering point of view, Propelloplanes pose no abnormally difficult detail design problems.

Hovering yaw and pitch control would be achieved by directing the exhaust gases from the aft fuselage located turbojet engines up, down, or transversely. Any downward directed tail turbojet exhaust gases would be swept away by the deflected propeller wake flowing over the surface of the ground. Recirculation of the hot turbojet exhaust gases into the turbojet engines' air intakes should thus not prove a problem.

Each of four dual-rotation propellers would be driven by at least two turbine-engine power sections. Controlled hovering flight would thus be made possible following the failure of any one power section. Interconnecting shafts—and their associated objectionable alignment and maintenance problems—are not required.

With fuselage-mounted landing gear and adequate propeller ground clearance available when the high wing is in the level position used for airplane-type flight, it is obvious that overload take-offs could be made as a normal airplane. Wing leading-edge slots could be used to take maximum advantage of the available variable wing incidence.

Forward speeds and rates of climb are typically several times those attainable by helicopters. The flexibility of operation permitted by airplane-type overload take-offs would permit this type of aircraft to be easily and rapidly self-ferried to any area that needs it.

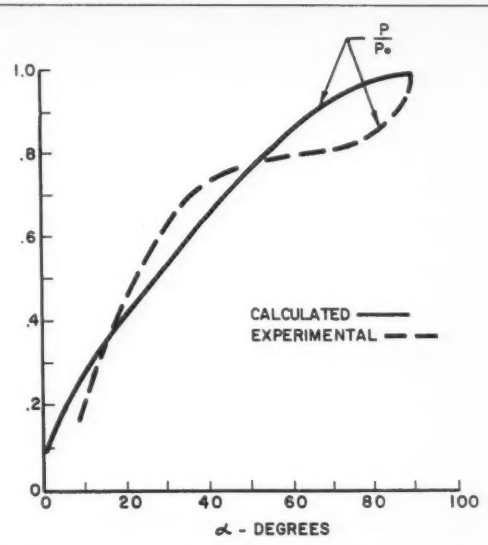

Fig. 4. Variation of power required with angle of attack.

Propelloplane Advantages

The major advantages offered by propeller-lifted, tilt-wing Propelloplanes may be summarized as follows:

(1) Propelloplanes combine the desirable hovering and vertical take-off and landing characteristics of helicopters with turbine-powered airplanes' advantages of high performance, low vibration levels, and superior forward flight, stability, and control characteristics.

(2) Acceptably low noise levels can be assured through the use of the relatively low propeller tip speeds appropriate for these high forward speed aircraft.

(3) Minimum, easy maintenance is assured by the use of independent, package-type power-plant installations and the avoidance of helicopters' flapping and lag hinges, lag hinge dampers, and interconnecting shaft systems that are difficult to install and maintain.

(4) Propelloplanes, with their much higher cruise speeds, should be able to achieve pay-load ton-mile operating costs substantially lower than those of helicopters. This basic advantage is supplemented by the operating flexibility added by their ability to take off as an airplane with even greater useful loads.[4]

(5) NACA quantitative tests of propeller tilt-wing combinations and the successful flight tests made with their free-flight tilt-wing models have amply demonstrated the high lifting efficiency and general technical feasibility of the Propelloplane concept.

(6) The possibility exists of economically and promptly developing effective, efficient, high-performance, vertical take-off transport Propelloplanes through the application of available gas-turbine engines and propellers. (This situation contrasts sharply with the many fundamental, time-consuming developments needed physically to realize other proposed VTOL aircraft types.)

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An Application of the Ducted Propeller to a VTOL Transport Airplane

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EVER SINCE the time of the Wright brothers, man has refined and developed his flying machines. This paper will concentrate on some of the future design thinking which is possible due to the success of the Bell VTOL air test vehicle[11] and will propose the application of some of the principles resulting from its tests to a vertical take-off and landing transport.

Long experience in the use of helicopters had convinced Bell Aircraft Corporation that vertical take-off capability was absolutely mandatory. Too many times had they found that even a few feet of ground roll could be too much if it was not available. The small sites hacked out of Korean mountain tops for helicopter operation had adequately demonstrated this thesis. The limited space aboard ship emphasized it. On the other hand, it was apparent to our designers that at times there were advantages in being able to execute a short ground roll for take-off. Distances of 200–300 ft. were not prohibitive in many situations, and the use of such distances greatly increased the load with which the airplane could get into the air. The answer was almost obvious. Design the airplane so that it had the VTOL capability but also so that it could take advantage of the existence of short take-off strips for overloaded take-off. The practical exploitation of this scheme dictated the use of a horizontal fuselage attitude on the airplane with a conventional-type landing gear which could be used for a running STOL.

Considering the general field, it appeared that a requirement might be developed for a VTOL airplane with characteristics lying somewhere between the helicopter and the jet VTOL. In order to examine such a requirement, it was desired to obtain a configuration which would have a vertical take-off and landing capability, a much better subsonic cruise speed than the helicopter, and better hovering efficiency than the jet-powered VTOL. Examining various methods of designing such a vehicle, Bell became interested in the ducted propeller because of its high static thrust and low fuel consumption.

If hovering efficiency is designated as a parameter roughly equivalent to thrust divided by fuel consumption, a comparison of hovering efficiency versus velocity capability would show a natural spread of VTOL types. The helicopter would be selected to represent a 100 per cent hovering efficiency. In general, its speed is limited to about 150 m.p.h. Slightly below the helicopter, at about 90 per cent hovering efficiency, a rotor-type convertiplane may be visualized showing a speed capability of 250–300 m.p.h. At the bottom of the spectrum, since they must support the airplane on pure jet thrust, the jet-propelled VTOL airplanes show a hovering efficiency of about 5 and 2 $^1/_2$ per cent. They are the best airplanes in terms of speed, however, the nonafterburning jet showing a speed capability of from 500–700 m.p.h.

The afterburning jet VTOL shows a speed capability extending well into the supersonic flight regime where it becomes closely competitive with projected fighter airplanes. In between, we would plot the characteristics of a hypothetical ducted propeller which was selected for its high static thrust potential. Since the ducted propeller converts shaft horsepower into thrust and the turboprop engine has a lower specific fuel consumption than the jet engine, it is possible to obtain about 40 per cent of the hovering efficiency of the helicopter. The ducted propeller has a speed range which can be extended easily up to 500 m.p.h. and satisfactorily fills the needed area in the spectrum of hovering efficiency and velocities of 300–500 m.p.h.

It may be asked why a bare propeller is not used to fill the same area. The ducted propeller appears ideally suited to the concept of the horizontal-attitude VTOL transport airplane from several aspects. Many investigators including Kucheman,[4] Weber,[4] and Kruger[7] in Germany, Platt[5] and Hubbard[9] of the United States, and Scholes and Patterson[6, 8] of Australia have looked at ducted propellers over the years. It is generally agreed that the addition of a shroud to the propeller results in at least a 25 per cent increase in static thrust for a propeller of fixed diameter and fixed power input. This increase in static thrust was of some interest to investigators of conventional airplanes but was usually passed over in favor of a bare propeller with a higher diameter in line with the lack of emphasis on static thrust. In addition to the static thrust, the shroud causes a reduction of the velocity effect on the

* Project Aerodynamicist.

propeller as the airplane moves from static conditions to high-speed flight. This has been considered, at times, as a possible means to simplify propeller systems by eliminating the necessity for variable pitch angle. The shrouded propeller can be designed to a higher r.p.m., thereby saving weight of gearing. Use of the shroud in a VTOL airplane is also valuable from the point of view of stability and control during hovering and transition flight. The extreme yaw angle effects on an open propeller blade are avoided by providing a faired inlet and ducting to allow a uniform channel for airflow into the propeller. Since the high yaw angle effects on the propeller can cause aerodynamic forces which will complicate the stability of the configuration during transition, it was judged advisable to avoid this situation. The use of the shroud around the propeller approaches the aerodynamic cleanliness typified by a jet source and presents advantages in still another field of interest—noise level. NACA experiments on shrouded propellers have indicated that the noise resulting from a propeller may be reduced by nearly 50 per cent through the use of a shroud.[9] This is a consideration which will become extremely important if a commercial transport application is considered. The advantages of a good structural arrangement for rotating the propeller and the safety features embodied in wrapping a shield around the rotating propellers are also worthy of note. Although it may appear that a shroud would add weight to the installation, it must be remembered that a bare propeller used on a horizontal-attitude VTOL usually requires long landing gear, extensive flap arrangements, or tiltable wings which also tend to increase weight and complexity.

The approach to this application of a ducted propeller involves using the shroud to reduce propeller diameters while maintaining a thrust-to-horsepower ratio of 3 to 5. This thrust-to-horsepower ratio can be obtained with a relatively high pressure ratio ducted propeller. The shrouding arrangement is visualized[3] as consisting of a duct which has a $1/d$ of from 0.5 to 1.0. This scheme has used a multiblade rotor carrying perhaps 15 to 20 fixed blades. A turboprop engine has been considered. Controllable guide vanes have been suggested to provide the variable geometry necessary for the range of 0 to 500 m.p.h. A stator section will probably be necessary to eliminate the swirl.

The duct arrangement must meet two considerations. In order to provide a useful increase in static thrust, a large-radius, bell-mouth inlet is deemed necessary, while the level flight condition requires the drag of the ducting to be minimized. At first glance these requirements appear to be incompatible, but a solution is possible with a compromise design which uses a series of extensible flaps to provide a large-radius inlet condition at take-off. Kruger[7] performed a series of tests in Germany during the early 1940's which indicated that such an arrangement could be used with success. These tests suggest that a retractable flap, which permits a simulated bell mouth at take-off and a low drag nacelle at flight speeds, would provide the benefits of the shrouded propeller in a high subsonic speed VTOL airplane.

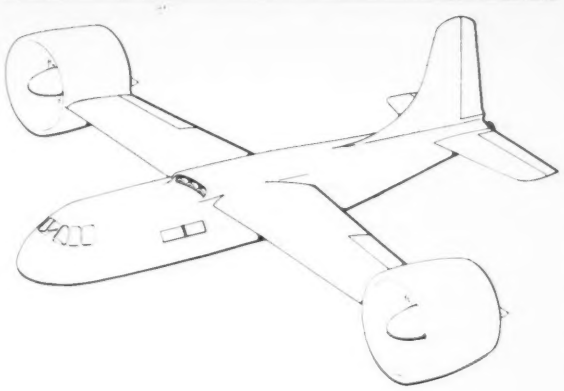

FIG. 1. Ducted propeller transport.

With this definition of a ducted propeller type, it is possible to design preliminary arrangements which offer an interesting vehicle. Using the transport application, a typical concept is shown in Fig. 1. The airplane is arranged to mount two shrouded propellers at the wing tips. The shrouds enclose about 11-ft. diameter, multiblade propellers of the type suggested. Retractable take-off flaps have been provided for high static thrust. Each shroud is rotatable through about 100° from horizontal. The engines are interconnected to all of the propellers and can be visualized as using mechanical shafting. The airplane was designed to weigh 35,000 lbs. and has a wing span of 83 ft. and an overall length of 55 ft. It is capable of lifting a payload of 4,000 lbs. in a vertical take-off and transitioning to level flight, or it can use an STOL to carry an overload in a running take-off.

It can be powered with a choice of currently available turboprop engines providing about 12,000 hp. In the vertical take-off condition, the flaps on the shroud are extended and the engines are rotated to the vertical or 90° condition. A thrust of 42,000 lbs. was considered available for take-off. This would permit a transition to level flight in about 35 sec.

Controls for the hovering condition, where the lack of airflow over standard aerodynamic surfaces prevents them from being used, is obtained with a combination of reaction control and spoilers located in the propeller ducts. Most turboprop engines have a residual thrust which is discharged through the engine nozzle. This is available in level flight for use as an additional thrust increment. In hovering flight, this same discharge air can be ducted aft to the tail and discharged through a variable-direction nozzle to obtain a pitch or a yaw control motion. This system will do little more than add a swiveling nozzle to the required tailpipe which is provided for the exhaust gases. Roll control during hovering could also be obtained with reaction controls, but a more attractive approach appears to be the use of spoiler controls in the prop ducts themselves. Plates, eyelids, or scissor-type flaps may be extended to reduce

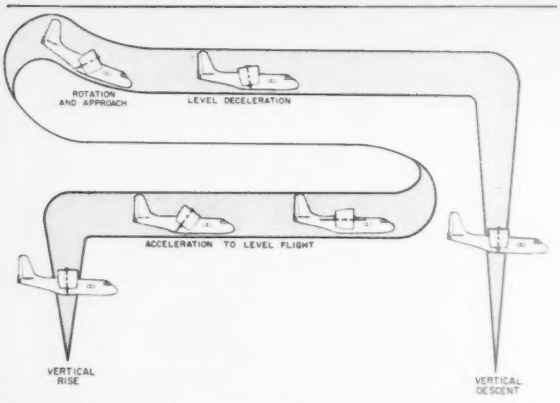

FIG. 2. Vertical take-off and landing (rotating ducted propellers).

the available exit area of the duct and hence vary the thrust of one of the shrouds. A system of this type would not be adversely influenced by the lack of airflow at the hovering condition.

From the performance standpoint, Bell felt that the airplane could follow a flight path made up of a vertical rise to a nominal altitude, followed by a translation from this position to the horizontal flight condition.[1] The general type of flight path is similar to that already used on the Bell test vehicle[11]. A schematic representation is shown in Fig. 2. The translation could be accomplished either by pitching the airplane nose down slightly or by rotating the engines. In both cases, the wing was maintained at an angle of attack less than stall angle as speed was increased. The gradual rotation of the shrouds provides the cosine component of thrust for lifting and the sine component for accelerations. A fixed rate of 15°/sec. shroud rotation was selected, and the pilot was given manual control of the time the rotation was applied. This, in effect, would give him the opportunity to apply rotation at various rates. The influence of the vertical rise velocity on the take-off path was investigated, and it became apparent that a nominal positive velocity would be satisfactory. Since the wing was at 90° angle of attack during this portion of the flight, it was advantageous to keep the velocity as low as possible. A 5 ft. per sec. velocity has been considered in this application. In the case of the air test vehicle, it was determined that the airplane, using the jet engine with its high fuel consumption, could actually be loaded up to the condition where thrust was equal to the weight and the rate of fuel consumption would permit the build-up to 5 ft. per sec. within a few seconds. The use of a negligibly small positive thrust margin at start of take-off permitted positive break-ground characteristics. Since this high loading permits the addition of more fuel, it is generally advisable to be loaded to this condition.

In the case of the ducted propeller transport airplane, this situation is somewhat changed. One of the reasons for the selection of the turboprop installation was a low fuel consumption. Therefore, a positive break-ground and build-up to 5 ft. per sec. velocity would be best obtained with a positive thrust of about 1.03 times the weight.

The landing path is visualized as a normal gliding approach at reduced power. As the airplane nears aerodynamic stall speed, the shrouds are rotated to a 100° position where power is applied. The build-up to full thrust unloads the wing and decelerates the airplane to hovering. Power is then reduced, and a vertical landing is made.

The airplane concept which has been used as an illustration would have a maximum speed capability of 430 m.p.h. A sample cruise calculation, based on a range plus a 60-min. hovering time, indicates that it would carry a pay load of 4,000 lbs. a distance of 581 miles at 250 m.p.h. and 3,000 ft. altitude. If it was desired to operate at higher altitudes, the range would be increased to 810 miles at 20,000 ft. The hovering capability of this airplane would be moderately good. A capability of 108 min. hovering time is available with standard pay load and zero range. At the range of 810 miles, 60 min. of hovering would be available.

Operation of the transport as an STOL airplane is considered an available secondary mission. Using a 400-ft. ground run distance and adding 3,500 lbs. of fuel to overload the airplane would increase the range with 60 min. hovering from 581 to 1,111 miles at 3,000 ft. Of course, the 400-ft. ground roll would also permit an increase of about 3,500 lbs. in pay load if the basic range figure was maintained.

Experience with the jet-propelled VTOL test vehicle indicates that the VTOL airplane needs only slightly more space for landing than the span of its wings. In the commercial sense, the airplane could be visualized in downtown areas for transport from business centers to long distance air lines. The air coordinating committee of the Air Transport Association in its study of the convertiplane gave some interesting statistics on the possibilities of this market. Fig. 3, taken from reference 10, shows a comparison of the timesaving available if a vertical take-off transport is compared with a fixed-wing airplane in short hauls. Even at a 200-m.p.h. cruise speed, the VTOL provides a substantial saving over a 250-m.p.h. fixed-wing airplane at

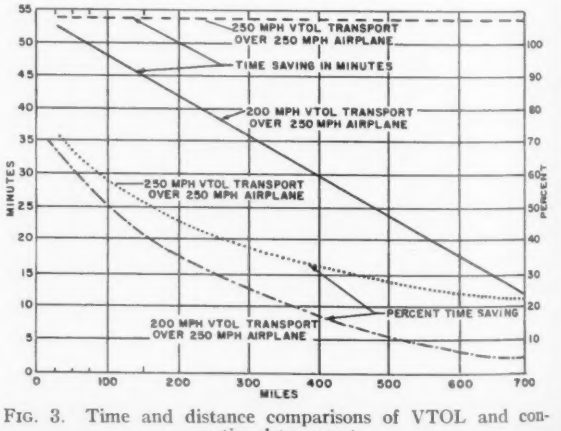

FIG. 3. Time and distance comparisons of VTOL and conventional transports.

cruise distances up to 600 miles. A VTOL with an equivalent cruise speed to the fixed wing increases this saving. The ducted propeller VTOL should be able to show cruise speeds of 300 m.p.h. with little difficulty.

The military utility of such a device is evident when it is considered that close aerial support of front line troops would be available to the commanders in the field. Supply transports would be able to move stores quickly up to the front line units. Troops could be shifted easily and quickly from one sector to another. The mobile army would be an established fact. We are sure that further research and design study can establish satisfactory types for a variety of missions.

The concept of the ducted propeller transport has been presented with a minimum of discussion on the VTOL performance, stability, and control problems. These fields of technical knowledge are basically derived from the work on the jet-propelled VTOL air test vehicle. Possible solutions for the transport application are best visualized by a review of the experimental flight tests conducted with this Air test vehicle.[11]

The success of these experiments in VTOL stability, control, and performance are best understood by considering the flight tests which were accomplished with this airplane. These tests evaluated the ground effects of the airplane, the hovering performance, the ability to translate from the hovering condition to a forward motion, and the effect of rotating the engines while in level flight and decelerating to speeds below the stall condition. Since this airplane was a test vehicle—a working model to sample the idea—it was not considered necessary to continue the testing beyond the point where the concept had been established. With the information obtained on hovering and translational flight, it was considered logical to conclude that a jet-propelled airplane of the horizontal-attitude type could hover, could transition into forward flight, could use a rotating thrust vector to accomplish the transition, and could be built from the present state of the art without requiring additional basic research.

The success of this test airplane set the stage for many practical applications of the VTOL principle. The jet applications are fairly obvious. In studying the needs and requirements of short-haul transports, the ducted propeller application has appeared increasingly attractive. A useful speed range, a vertical take-off, and a moderately efficient hovering capability are the basic ingredients which make this configuration attractive. Having obtained a vertical take-off capability and a moderate hovering efficiency, the vehicle is useful in direct proportion to the speed with which it can travel.

From this standpoint, the ducted propeller VTOL airplanes are worthy contenders for that area of the spectrum which lies between the helicopter and the jet VTOL.

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A review of the noise fatigue problem discussed in four parts: response of systems to various types of inputs, near field characteristics of various noise sources, vibration modes, and fatigue. Emphasis is on concepts and orders of magnitude.

Noise, Vibration, and Aircraft Structures*

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Langley Aeronautical Laboratory, NACA

Introduction

Ever since multiengined aircraft have been in general use, there has been the problem of making the structural areas near the propellers and jets sufficiently strong to avoid fatigue due to noise. The much larger power plants becoming available have greatly aggravated the problem of noise fatigue to the extent that noise damage is becoming an important consideration in the determination of aircraft configurations.

A rough idea of magnitudes of the sound pressures that are of current interest is illustrated in Fig. 1. The range of pressures is expressed as decibels and as pounds per square foot. Gun blast pressures are included in this figure because they represent experience with pressures of a different order of magnitude but one which is being approached by some of our modern propulsive systems. Pressure fluctuations in the order of 180 db. or 1/4 atmosphere are produced near present propulsive systems and on aerodynamic surfaces subjected to shock buffeting.

Most aircraft skins and secondary structures will show fatigue damage after many cycles, when subjected to pressures ranging from 140 to 150 db., and permanent set or rupture after short exposure to 180 db.

Input-Output Relations

In this paper the inputs considered are the noise pressure loadings; the outputs are the stresses in the structure. Noise inputs may be divided into three general classes: (1) discrete frequency—for example, propellers; (2) random frequency, as from jets; and (3) impulsive, as from gun blast or starting of rockets.

Presented at the Aircraft Noise Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* For additional illustrations and descriptive text, see IAS Preprint No. 631.

† Head, Vibration and Flutter Branch, Dynamic Loads Division.

Discrete Frequency Input

An example of the significant input-output relations for a discrete frequency input is shown in Fig. 2. Most discrete frequency sources do not produce a pure tone of single frequency, but one rich in harmonics. As illustrated at the top of the figure, the pressure amplitude of each frequency component is indicated by the height of the bar at that frequency. The admittance of the structure is illustrated in the second graph. This is often referred to as the response curve; the peaks in the curve correspond to the various resonances in the system. The height of the admittance curve at any frequency relative to its value at zero frequency is the dynamic amplification. This dynamic amplification may go as high as 50 or more. The admittance may be considered as the stress at a particular point in the structure per unit pressure applied at the input point or area. The output is the product of input and the admittance. It, too, is a line spectrum for, if the system is linear, it can vibrate only at the frequencies at which it is forced by the input. The magnitude of the stress at a given frequency depends on both the input and the admittance, and from a practical standpoint much can be done to minimize stresses by changing both the input and the admittance.

Random Inputs

In considering the response to random frequency inputs, one deals entirely in probabilities. A classic problem along these lines was worked out by Lord Rayleigh.[1]

Recently there has been considerable activity in the application of statistical properties of random functions to such problems as gust response, buffeting, and response to random noise.[2,3] This type of analysis is usually referred to as generalized harmonic analysis, and some of its concepts are illustrated in Fig. 3. There is considerable similarity between this figure and

the preceding one. One of the differences is that now one deals in squares of the quantities—that is, one might consider that the problem is cast in terms of energy rather than in terms of force or pressure. The input expressed as pressure squared per unit band width varies only gradually with frequency, having all frequencies present. The output also has all frequencies present. The value of the mean-square stress is given by the area under the output curve.

Contrary to the case of discrete inputs, for random inputs small changes in the shape of the input spectrum or in the admittance curves have only secondary effect on the area under the output curve—the mean-square stress. Damping reduces the stresses—i.e., directly as the square root of the damping. However, the problem of obtaining damping materials and devices to withstand the high noise levels encountered has not been satisfactorily solved.

As was discussed with respect to Fig. 2, Fig. 3 might be considered the stress at a point due to a random load at another point. In order to find the total stress at this point, one should know the loads at other points of the structure, the pertinent admittance curves, the phases of the admittance, and the space-time correlations of the input.

Impulsive or Blast Loading

Impulsive loadings are applied to aircraft structures by gun blasts, rocket ignition, shock waves from other aircraft such as sonic booms, and blasts from bombs or warheads.[4, 5] Some of the characteristics of impulsive loading and the response of the structure are shown in Fig. 4. This information is taken from reference 4, which gives a comprehensive treatment on structural damage due to gun blasts. The upper left-hand part of the figure illustrates a typical time history of a blast: a positive phase having a peak pressure by P_0 and then a negative phase of longer duration but lower peak value. The lower left illustrates a smoothed curve of the strain at a point in the panel. This shows that the response of the panel is a damped oscillatory transient of a period usually corresponding to a fundamental frequency of the panel.

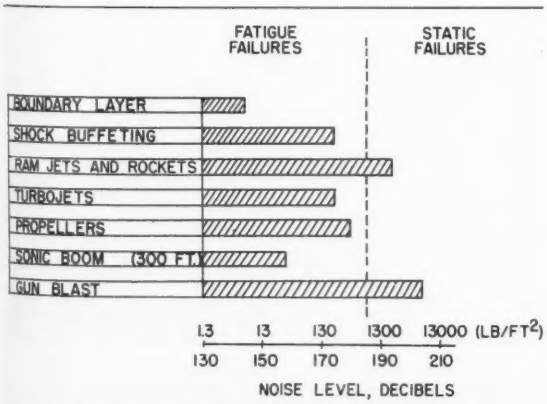

FIG. 1. Levels of noise loading on aircraft structures.

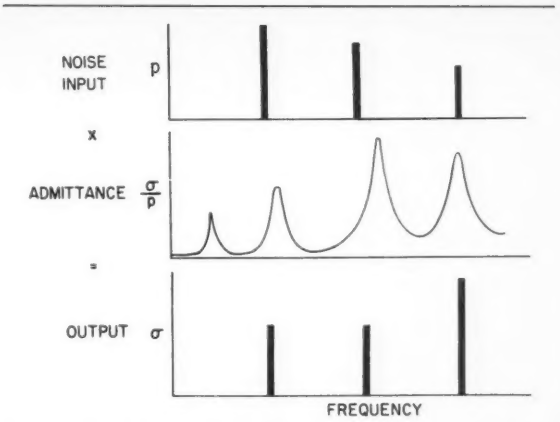

FIG. 2. Input-output relations for systems subjected to discrete frequency loading.

The dynamic amplification of the panel is illustrated on the right side of the figure as function of the ratio T/τ. The dynamic amplification is defined as the ratio of the maximum vibratory stress at the first positive peak (A) to the stress the plate would have if the peak positive blast pressure P_0 were applied as a static pressure. The lower curve refers to the negative peak stress relative to the same pressure P_0.

NEAR FIELD NOISE

The noise of most aircraft sources is usually different in frequency content, and varies differently with speed, for a point near the source as compared with a point a few wave lengths from the source. This is principally due to two things: (1) aircraft sources are usually distributed; and (2) the various pressure components decrease with different power of the distance.

To illustrate the first point, the sounds one hears in the percussion section of an orchestra are different from those one hears in the violin section, and they are still different from the sounds one hears at a choice seat in the auditorium. In a similar manner, the noise very near a jet nozzle is different from that very near the jet farther downstream where large-scale turbulent mixing occurs—and it is still different some distance away where one obtains the integrated effect of all regions of the jet.[6]

The second reason for differences between near and far fields lies in the fact that a large portion of the pressures at the source are balanced by the inertia of the fluid and are not radiated as compression waves in the fluid. Thus, for a dipole source (source-sink) much of the pressure field varies as the inverse square of the distance, whereas the radiation pressures vary as the inverse first power of the distance from the source. For a double dipole or quadrupole, the pressure varies as inverse distance cubed and squared, as well as the inverse distance for the radiation pressure.[7]

Propellers

Some practical implications of these factors are illustrated in Fig. 5 which compares the pressure varia-

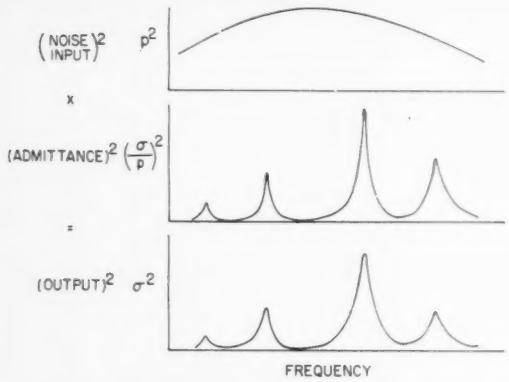

FIG. 3. Input-output relations for systems subjected to random frequency loading.

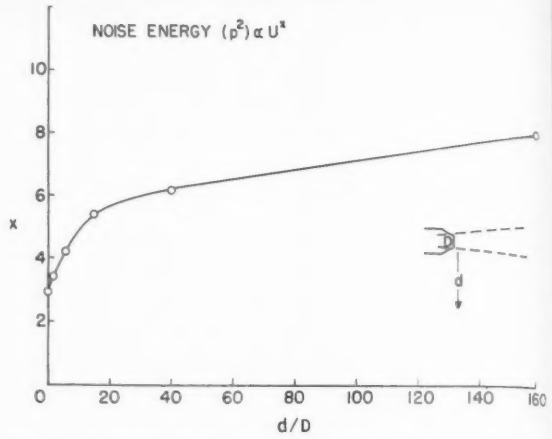

FIG. 6. Variation of the exponent relating sound energy to jet velocity as function of distance from the jet.[39]

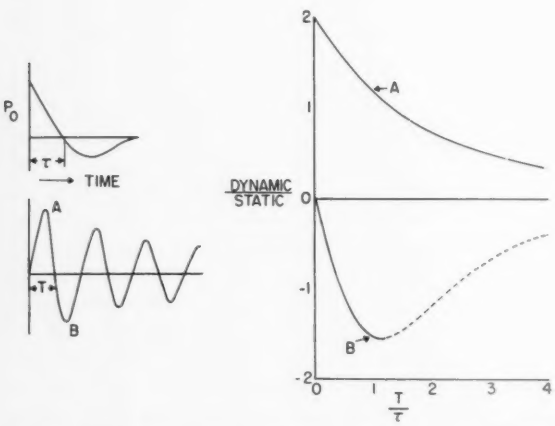

FIG. 4. Input-output relations for systems subjected to impulse loading.

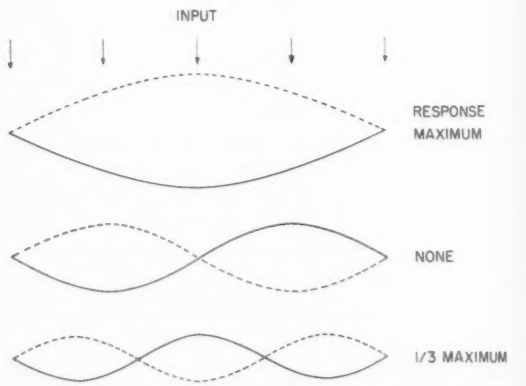

FIG. 7. Schematic diagram illustrating effect of vibration mode shape on response to plane wave noise excitation.

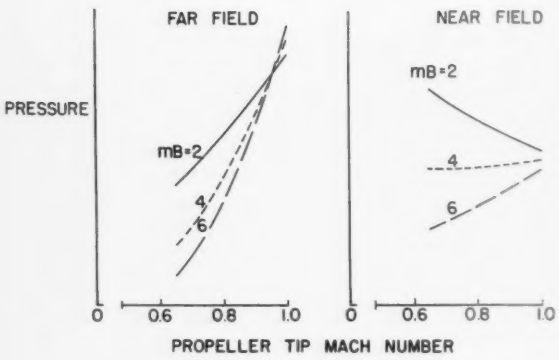

FIG. 5. Comparison of near and far field propeller noise.

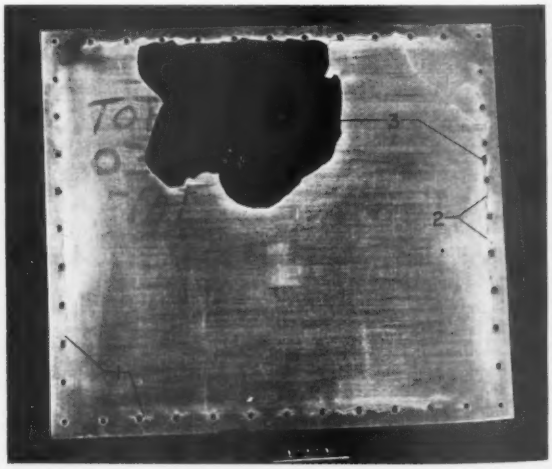

FIG. 8. Sample flat panel failure from siren tests ($t = 0.032$ in.).

tion with propeller tip speed at distances in the order of 1/10 diameter from the propeller tip with those one might expect a few diameters or more from the propeller.[8] A word of caution needs to be said with respect to the ordinates in this two-part figure. The near field pressures are plotted to a different scale and are much higher than the far field pressures. The symbol m is the order of the harmonic—1 for the fundamental, 2 for the second harmonic, etc. B is number of blades. Thus, $mB = 2, 4, 6$ may be construed as the fundamental frequency of a two-, four-, or six-blade propeller or the first three harmonics of a two-blade propeller. The main point of interest is that for constant power, at several diameters from the propellers (far field), the pressures rise rapidly with increasing tip speed, whereas very near the propeller, the pressures may increase or decrease with tip speed depending on the value of mB.

Jets

Some near and far field comparisons for the noise from model jets[9] are shown in Fig. 6. Here is plotted the exponent of the jet velocity (which relates the noise energy to the velocity) as function of the distance to the nozzle. The direction of the field point is 90° with respect to the jet axis. Far from the nozzle, the noise energy varies as the eighth power of the velocity, as predicted by theory.[10] However, near the nozzle, the noise energy (specifically $p^2/\rho c$) varies only as the third power of velocity. (See also reference 11.) Thus, the noise pressures near a jet will vary less drastically with velocity than they do at some distance away from the jet.

Further discussion of the near field pressures from jets and the turbulence in jets may be found in references 6 and 9 to 18. Currently there is considerable interest in the space-time correlation for near field jet noise, and work along these lines is proceeding at the NACA.

Aerodynamic Noise and Buffeting

There are reasons to believe that, for jet aircraft at high-flight speeds, the principal source of structural excitation will be that due to aerodynamic noise and buffeting. How serious this problem may become at transonic and supersonic speeds has not been determined. Cases of structural failures are known to have occurred in regions of flow separation, such as behind spoilers and wing fuselage junctures.

Some values of the pressure fluctuations in the boundary layer of subsonic aircraft are presented in reference 19. These values were obtained by correcting sound reading in the aircraft for wall transmissibility.

Vibration Responses

The effect of vibration mode shape on the response of a structure to a plane wave of sound is illustrated in Fig. 7. It represents the case of a plane wave traveling perpendicular to a beam on simple supports. For the noise to do work on the structure, the pressure must have a component in phase with the velocity of the structure. In the fundamental mode, all parts of the structure are moving in the same phase, and a maximum energy can be absorbed. In the second mode, half of the structure is moving out of phase with respect to the other half, and no energy is absorbed. The plane wave cannot excite this vibration mode. In the third mode, two loops cancel each other, and the structure can absorb only one third the energy it would if all were moving in phase. In general, one might expect less and less response with increasing order of vibration mode, when the excitation is a plane wave in phase over the area. However, when the noise is not in phase over the structure, one may well have conditions in which maximum stresses occurred in some higher vibration mode.

One of the questions that is often raised with regard to the response of aircraft structures is: "How important is air damping as compared with structural damping?" Some theoretical studies made for various modes of vibration of cylinders are presented in references 20 and 21. The case of panels, pistons, and numerous other shapes is treated in standard acoustic books such as reference 22. An application of this analysis to aircraft structures shows that, because of three-dimensional effects, the reaction of the air on the structure is mainly as an added mass and that the radiation damping is usually negligible. This is contrary to what one would expect from plane wave acoustics, in which all the air reaction results in radiation damping.

When subjecting a complex aircraft structure—such as a cylindrical fuselage—to random noise, many vibration modes are excited to some extent, and, by making a narrow band frequency analysis of a strain-gage recording, many modes can be identified. So far we have not been able to predict which modes will produce the highest stresses. It had generally been thought that only the lowest modes were important from a stress standpoint; yet when we extend the frequency range of our recording equipment to higher frequencies, we find more of the larger stresses at the higher frequencies. What part these higher frequencies may play in fatigue has not been determined.

Fatigue

The field of fatigue is an extremely old field of research, yet, in spite of its age, one can talk of result only in terms of probabilities and wide scatter bands. This is true because microscopic variations in a specimen may have a profound effect on its fatigue life. Results of noise fatigue generally follow in the same pattern, and it is not yet clear what the new elements in the problem are. Some recent review papers giving the findings and philosophies in the aircraft fatigue field are listed in references 23 to 26.

Although a considerable amount of information undoubtedly exists on noise fatigue and fixes, there has

been little published on this subject. Perhaps one of the most systematic studies along these lines was made by The Glenn L. Martin Company with regard to seaplane hull plating fatigue.[27] Another reference on noise fatigue is the work of Northrop Aircraft, Inc.[28]; gun blast damage is discussed in reference 4. The Boeing Airplane Company has done extensive work in noise fatigue, and some of the techniques they have pioneered are being used at other laboratories.

From a perusal of these references, one is struck by the fact that stress raisers have little effect on ultimate strength but a large effect on fatigue.

In order to study some of the variables in the problem of fatigue due to noise, the Langley Laboratory of the NACA has recently tested a number of panels with an intense noise of discrete frequency produced by an air chopper. The test setup is similar to that used by the Boeing Company. An illustration of a fatigue failure obtained on a flat panel[29] (11 by 13 by 0.032 in. 2024T3 Alclad) is shown in Fig. 8. The panel was fastened to a rigid frame with round-head screws. By looking closely at the picture, one can see the fatigue damage in various stages of progress, from the incipient cracks around the rivets to large pieces blown out of the panel. This latter is a characteristic of noise damage if the tests are not terminated soon enough.

Conclusions

We have presented a brief review of the problem of noise, vibration, and aircraft structures. One finds many complications of such dimension that it is doubtful whether predicting noise fatigue will ever become possible to better than an order of magnitude. From a study of the input-output relations, one can often obtain valuable guidance for obtaining fixes to specific problems. For simple panels some success at stress prediction in random noise fields has been obtained.[3,29]

Although some progress has been made, the field has hardly been explored. Much more information is needed on the magnitude, phases, and various correlations of the inputs of near field noise, particularly for the random sources. Information is needed on the response of structures and the critical stress areas for each mode of response, and, lastly, a great deal of information is needed on the fatigue of skin structure and its supports when subjected to the type of loading imposed by noise.

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Prediction of Downwash at Various Angles of Attack . . .

(*Continued from page 27*)

ever, is capable of extension to flaps-down configurations. It is recognized that each of such configuration features as the fuselage, nacelles, fences, and slats has an influence on the downwash angle and must be considered before a configuration may be finalized. The wing, however, remains the primary element of the configuration which influences the downwash at the tail.

Conclusion

The procedure outlined in this paper appears to be well adapted to predicting the downwash at the horizontal tail during preliminary design studies. The prediction of the nonlinear downwash characteristics was good for the cases investigated, and the method requires relatively little time and effort.

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The Turbine-Propeller Combination . . .

(*Continued from page 43*)

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IAS News

(*Continued from page 15*)

Bruno J. Salvadori (M), formerly Executive Chief Engineer of Bellanca Aircraft Corporation, has joined the staff of All American Engineering Company, Wilmington, Del.

Arthur Schnitt (M) has been promoted to Chief of Structures, Bell Aircraft Corporation. He was formerly Assistant Chief.

William T. Shuler (M) has been appointed Structural Analysis Engineer of the Georgia Division of Lockheed Aircraft Corporation. He came to Lockheed from Headquarters, USAF, Washington, D.C., where he had been responsible for operations analysis of employment of tactical missiles weapon systems and general air-frame and aerodynamics consulting activities.

Reuben P. Snodgrass (TM) has been appointed Director of Flight Research of the Sperry Gyroscope Company Division of Sperry Rand Corporation. He was formerly Engineering Department Head for Flight Research.

Don D. Warner (M) has been appointed Chief of Structures, Northrop Aircraft, Inc. He was formerly Structures Supervisor.

Omer Welling (AF) has been promoted to Deputy Director of the Office of Aviation Safety, Civil Aeronautics Administration, U.S. Department of Commerce, Washington, D.C. With the CAA since 1936, he was formerly Chief of its Aircraft Engineering Division in Kansas City, Mo.

Robert M. Williams (M) has joined Embry-Riddle International School of Aviation, Miami, Fla., as Director of Engineering. He was formerly Head of the Dynamics and Fatigue Section, Engineering Test Laboratory, Lockheed Aircraft Corporation, Marietta, Ga.

Arthur J. Williamson (M), formerly Vice-President, has been elected Executive Vice-President of the Tube Reducing Corporation, Wallington, N.J.

CORPORATE MEMBER NEWS

• **Airborne Accessories Corporation** announces two new linear actuators, the R-5140 and R-5160 series. They operate on 26 volts d.c.

• **Aluminum Company of America** will install a 14,000-ton extrusion press in its Lafayette (Ind.) works at a cost of $9,000,000, the company announced. An identical press, owned by the Air Force, has been in operation in the same plant since 1954. The new press, which will be ready for operation early in 1959, will be used to make ribbed wing sections, wing spars, rotor blades for large helicopters, and structural shapes up to 110 ft. in length and weighing up to 2,500 lbs. In the same Alcoa plant is a mammoth "stretcher" with a pulling force of 3,000,000 lbs. This machine straightens the big extrusions and relieves internal stresses.

• **American Phenolic Corporation** has changed its name to Amphenol Electronics Corporation. The Directors of the Chicago electronics firm recently promoted Rodolfo M. Soria to Vice-President in charge of Engineering.

• **Beech Aircraft Corporation** . . . A test quantity of the XKDB-1 target plane has been delivered to the Navy, and the all-metal drone is now undergoing flight evaluation tests at the Naval Air Missile Test Center, Point Mugu, Calif. The remote-controlled, pilotless aircraft has a 12-ft. wing span and weighs 600 lbs. Capable of flying 320 m.p.h., it can stay above 30,000 ft. for an hour. For visual identification, it leaves a smoky trail. The drone is recovered by parachute for repeated use as a target.

• **Bendix Aviation Corporation** . . . A new series of waterproof, shock-resistant electrical connectors with five assembly styles has been introduced by the Scintilla Division, Sidney, N.Y. This series, designated QWL, is being used with multiconductor cable on launching equipment for missiles, ground radar units, and on heavy construction and oil-field equipment.

• **The Cleveland Pneumatic Tool Company** . . . The National Water Lift Company, a Division in Kalamazoo, Mich., has doubled its test facilities for research and development in the field of high-temperature hydraulic operation. New equipment duplicates the high-temperature conditions encountered in subsonic and supersonic jet and rocket flight.

• **Cornell Aeronautical Laboratory, Inc.** . . . The large wind tunnel at C.A.L. is shut down for 3 months this summer while new equipment is being installed and further alterations are being made under a $2,000,000 modification program. When the tunnel is reopened late this year, it will have an 8- by 8-ft. transonic test section capable of operating at all speeds up to Mach 1.30. . . . C.A.L. is engaged in a study of exhaust contrails for the Office of Naval Research and the Bureau of Aeronautics. The program is directed primarily at the development of refined criteria on which contrail forecasting can be based. . . . A study of the strength characteristics of titanium at elevated temperatures has been undertaken for Boeing Airplane Company. . . . C.A.L. will conduct a year's study of long-distance transmission of UHF radio signals for the Electronics Research Directorate of the Air Force Cambridge Research Center. With a transmitting station and a receiving station 395 miles apart, the Laboratory scientists will attempt to prove that reliable transmission can be attained by tro[po]spheric scattering, which propagates small part of the signals beyond the line[-of-] sight horizon, and by capturing the sign[als] beyond the horizon with large anten[nas] and very sensitive radio receivers. . . . C.A.L. is assisting the Airborne Inst[ru]ments Laboratory, Inc., in a long-ra[nge] study of aircraft and air traffic cont[rol] for the federal Government's Air Facili[ties] Planning Committee. The study w[ill] cover civil and military planes that a[re] expected to be in use during the next [10] years.

• **Curtiss-Wright Corporation** . . . T[he] Electronics Division, Carlstadt, N.J., h[as] placed on the market the Radiameter, [a] lightweight instrument which detects an[d] measures potentially hazardous atom[ic] radiation in industry or X-rays in me[di]cine. The unit weighs 2 lbs., fits in a lar[ge] pocket or a carrying case, and operates [on] a flashlight battery. It meets the re[-] quirements of the health physicist, a ne[w] type of scientist who directs the safe appli[-] cation of nuclear and X-radiation. Th[e] Radiameter may be used for periodically monitoring installations and X-ray ma[-] chines to assure the safety of personnel.

• **Douglas Aircraft Company, Inc.** . . . Th[e] carrier-based F5D Skylancer, which mad[e] its first flight April 21, has passed the speed of sound in subsequent test flights at Edwards Air Force Base, according to an official announcement. The all-weather fighter, designed for catapult take-off, is powered by a Pratt & Whitney J57 turbojet engine with afterburner. . . . Delivering the last of 670 AD-5's to the Navy recently, Douglas announced that it has built more than 3,000 planes of the carrier-based Skyraider (AD) series since 1945. The AD-6 and AD-7 versions are still being manufactured at El Segundo. . . . The Douglas DC-7C air liner received its airworthiness certificate on May 17 and is already being used in intercontinental service. The 350-m.p.h. transport carries from 48 to 105 passengers and has a range of 5,000 miles—sufficient to permit nonstop crossings of the North Atlantic in either direction. . . . The Charlotte Ordnance Missile Plant in Charlotte, N.C., has been opened as the fifth division of Douglas Aircraft Company, Inc.

• **The Dow Chemical Company** . . . Production at the magnesium rolling mill in Madison, Ill., has been increased nearly one third over the 1955 figure as a result of greater operating efficiency, the company reports. Output of rolled sheet and plate for the first 4 months of this year was 31 per cent higher than the monthly average last year. The mill has been in operation 2 years. Dow has adopted the new military thickness standards (MS33528) for aircraft sheet and is now producing all magnesium FS1 alloy sheet in the weldable grade.

• **Elastic Stop Nut Corporation of America** announces a new line of miniature self-locking anchor nuts for fastening applications where space allowables are reduced to a minimum and low weight is of paramount importance. Intended for use in the constantly shrinking electronic units, the lightweight "space savers" meet the same tensile, vibration, and temperature requirements as standard AN366

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THE PROGRESS TEAM

Progress in design, development and engineering of military electronics is, in part, due to the contributions of "this man." *He* is the hard core of scientists and career engineers serving the Department of Defense as liaison between military need and industrial accomplishment. *He* translates operational requirements into technical specifications... paces equipment development... evaluates results. *He* is recognized as an all-important link between industry and military... helping to achieve OPERATIONAL RELIABILITY. This is teamwork... the indispensable ingredient which assures the quality of military electronic systems which this Company produces.

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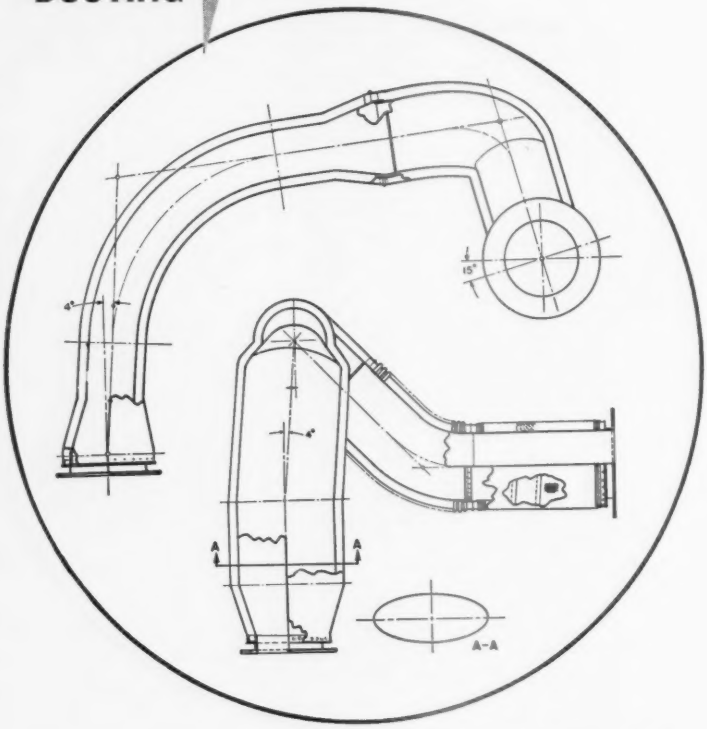

Check *FLEXONICS* for any of these components

FLEXON DUCTING, standard or high strength corrosion resistant, is available in varying wall thickness in light gauges and in a complete range of sizes, with or without insulation. Elbow forming and rib reinforced types can also be supplied in Type 321 and Uniloy 19-9DL.

FLEXON METAL HOSE, corrosion resistant, is manufactured in the broadest varieties of sizes and types for all aircraft applications.

FLEXON BELLOWS are made in an almost unlimited range of sizes and types to meet the most advanced requirements.

The ducting assembly illustrated above is typical of many intricate sections developed and fabricated by Flexonics to meet the rigid demands of high performance aircraft.

This particular unit is made for a new high altitude fighter and is designed for operating temperatures up to 760° F. Unusual in its design is the combination of circular, elliptical and flexible sections. To provide required uniformity, it is formed from Flexon straightwall stainless steel tubing, not half shells, welded together. The entire unit is insulated and the insulation sealed in a stainless steel outer shell to prevent wicking of volatile fluids.

Flexonics Corporation's ability to fabricate ducting of this type results from over 53 years' experience in the manufacture of flexible metal components. Put this know-how to work for you . . . it is your best assurance of getting the quality you need in your ducting requirements. For specific recommendations on the resolution of your ducting problems send an outline of your requirements.

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locknuts of similar configuration. Available in four thread sizes, the three configurations may be used at temperatures up to 500°F.

• **Fairchild Camera and Instrument Corporation . . .** A "motion-analysis" camera capable of taking high-quality pictures within the range of 5,000 per sec. has been designed by Fairchild and is now being field-tested. The lightweight 16-mm. camera has been designed for several different uses. An industrial model has been planned which will take up to 5,000 pictures per sec.; an air-borne model will operate at the rate of 2,000 per sec.; and a missile hit-miss model, which has already made 250 pictures per sec., is being improved to take 1,000 per sec. Both the industrial and air-borne models have film capacities of 100 and 200 ft., using daylight loading spools. The Fairchild Motion Analysis Camera utilizes a rotating prism, which was selected for the highest possible index of refraction and lowest dispersion with a minimum thickness and minimum angle of incidence. The result is an evenly illuminated picture that has a sharp frame line, with no overlapping of images of one frame into the next. The four-sided prism is made of a glass which does not cause "color fringing," and therefore color photography is possible without the use of color-correction filters. The rotating prism shaft is so mounted that the camera will operate at 55*g*'s shock without causing optical distortion or malfunction. It is possible to make single-frame enlargements from the original film. Picture steadiness on projection is superior to that of intermittent cameras shooting 64 pictures per sec., the company claims. The new camera is expected to prove useful in photographing high-speed electrical phenomena, automatic machinery, explosions, guided missiles, hydraulic phenomena, deceleration tests to simulate gravity pull, and fast motion in the sports and entertainment fields.

• **Fairchild Engine and Airplane Corporation . . .** Stratos Division, Bay Shore, Long Island, N.Y., has issued a leaflet entitled *Complete Accessory Systems for Many Basic Aircraft Services.* It describes aircraft pressurization and air-conditioning systems, high-pressure pneumatic systems, controls and valves, and pneumatic accessories.

• **Federal Telecommunication Laboratories** has begun publication of a four-page paper for its employees. Called *In the News*, the paper will be issued monthly. . . . Henri G. Busignies, formerly Executive Vice-President, has been named President of Federal Telecommunication Laboratories, which is the American research organization of International Telephone and Telegraph Corporation. An authority on radio and electronic aids to aerial navigation, Mr. Busignies holds more than 100 patents in the aerial navigation, radar, and communications field.

• **Flight Refueling, Inc. . . .** Albert Roeper, Controller, has also been elected Treasurer of the company.

• **The Garrett Corporation's** Aviation Service Division has moved into its new $600,000 facility at Los Angeles International Airport. The new base, not far from the former one, includes a hangar

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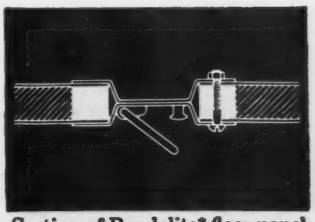
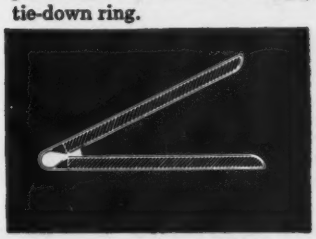
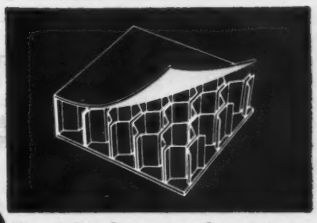


Section of Bondolite* floor panel (*T. M. Goodyear Aircraft Corporation) with inserted cargo tie-down ring.



Wing flap section made from Bondolite. Bend is reinforced with Epon Adhesive VI.



Bondolite honeycomb construction. Epon Adhesive VI bonds aluminum skin to central aluminum honeycomb.

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Epon adhesives have been used successfully in bonding metal, plastics, rubber and wood for helicopter rotor blades, honeycomb wing sections, jet fuel tanks, radar antennae, structural joints and floor panels. Can Epon adhesives solve an assembly problem for you? Write us about your problem and we'll send full technical information and samples.

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A light plane equipped with Goodyear's experimental low-pressure tires takes off from the grass at Akron Municipal Airport. The barrel-shaped, flat-sided tires are 24 in. wide and can be inflated at 3 to 8 psi. The Terra-Tires will later be tested on plowed fields, rough clearings, sand, snow, and marsh. The pliable tires conform to uneven surfaces without resisting them and glide over soft spots without bogging down.

300 by 300 ft. with four bays, each large enough to accommodate a four-engined air liner. The hangar, administration building, and shops are on a 25-acre plot.

• **General Dynamics Corporation** has been selected to design and construct a control system for the nozzle of flexible ducting which regulates the flow of air through the test chamber of the giant supersonic wind tunnel under construction at Arnold Engineering Development Center, USAF, Tullahoma, Tenn. Capable of operating continuously at Mach 4.5, the tunnel has a test section approximately 16 ft. square. The Electric Boat Division will supply the system of motor drives and mechanical jacks that will bend the flexible plates of the nozzle. The jacks must travel an extreme distance of 8 ft. within an accuracy of 0.008 in. The Stromberg-Carlson Division will create a digital computer system for automatically controlling the shape of the nozzle with electronic controls. . . . Convair-San Diego Division has broken ground for a $3,500,000 supersonic blowdown tunnel. It will be capable of testing models at subsonic, transonic, and supersonic speeds up to Mach 5.0 in a test section 4 by 4 ft. The runs will range from 50 to 90 sec. and can be repeated in 20 min. Air will be stored under a pressure of 600 psi (42 atmospheres). The flexible nozzle will be 38 ft. long. Closed-circuit television will permit observation of the model, replacing the usual glass window. The wind tunnel will be completed by next summer.

• **General Electric Company . . .** A giant computing machine that could save up to 2 years in the costly development of jet engines has been built by G-E for the Air Research and Development Command. The analog computer will become the brain of a jet-engine simulator now under construction for ARDC by the Aircraft Gas Turbine Development Department. It will enable engineers to forecast performance characteristics of control systems for jet engines that are still on the drawing boards. Previously, it has not been possible to check out a preproduction engine control system on a sufficiently large number of engines of one type. In many instances, either the engine is not available and its expected performance data are lacking or, if the experimental engine is available, engineers are unwilling to risk the expensive prototype in gruelling tests. Checking out an experimental engine control system normally requires up to 6 months and costs several million dollars in the wind-tunnel and flight-test phases. The new computer, which required 6 years to build, measures 35 by 100 ft. and is 12 ft. high. It contains 6,000 vacuum tubes, 1,700 indicating lights, and 2,750 knobs or dials. The apparatus is cooled by a large air conditioner. About 42 man-years of work went into the finished product. Approximately 8,350 man-hours were spent in the drafting stage, 44,960 in engineering, and 32,000 in manufacture and assembly. . . . The Silicone Products Department, Waterford, N.Y., is now manufacturing a silicone rubber cloth coating compound for ducting which can carry air at temperatures as high as 700°F. and remain flexible at −120°F. This compound, designated SE-701, is used in hot air ducts, jet-engine starter hose, aircraft fire-wall seals, and flexible connectors for metal ducting. . . . A new hermetically sealed, subminiature relay that eliminates "blind assembly" has been announced by the Specialty Control Department. Intended for use in aircraft, it can withstand shock of 50*g* and ambient temperatures up to 125°C.

• **General Precision Equipment Corporation . . .** Kearfott Company, Inc., has made a licensing agreement with R. B. Pullin & Company Ltd., of London, England, permitting the manufacture in England of servomotors, synchros, tachometer generators, and servomotor-tachometer combinations.

• **G. M. Giannini & Co., Inc.,** announces a new oil-filled rate gyro which incorporates a nonheated temperature-sensitive mechanism to maintain a linear damping over the ambient temperature range of −54° to 71°C.

• **The B. F. Goodrich Company . . .** A hose that remains strong and flexible at temperatures between −100° and 450°F. is being manufactured by the B. F. Goodrich Industrial Products Company, Marion, Ohio. It will be used for fuel, lubricant, and hydraulic lines in jet planes, rockets, and guided missiles. Made of tetrafluoroethylene (Teflon), a resin highly resistant to corrosive fuels, synthetic lubricants, and other chemicals, the light-weight, seamless hose is reinforced with braids of stainless steel wire. Goodrich is producing the new hose under a license agreement with Resistoflex Corporation, Belleville, N.J.

• **Lear, Incorporated,** has applied for patents on a small "black box" that exercises man-like powers of deliberative judgment. The company announced recently, adding that its first use will be for aircraft navigation. The device is said to follow precise rules of logic in "reasoning" whether to accept, reject, or demand confirmation of data fed into it. The system provides basic new methods of discriminating automatically between data from any two information sources. It does this through continuous electronic application of the laws of probability and error distribution, in order to deduce from two sets of data, each having known chances of error, intelligence more accurate than either conventional source could possibly provide.

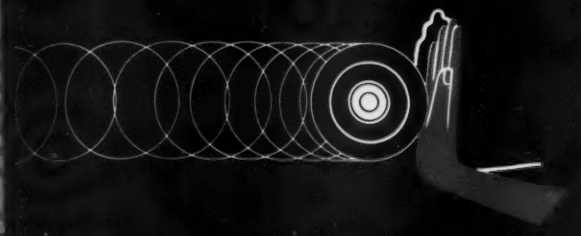
In its immediate air-borne applications, the system is called the Lear SCAN, meaning Self-Correcting Automatic Navigator. It will enable an airplane to fly straight to its target over enemy territory despite any attempts at electronic jamming, and without disclosing its presence by emitting any radiation. This technique will make use of reflected VHF signals far beyond the line of sight to which such signals are normally confined, thus permitting the plane to penetrate through mountainous terrain at low levels, avoiding radar detection. Only those signals are accepted which fall within the error limits of the air-borne navigating system. Once determined valid, the "good" radio data are then used to correct automatically the reading of the air-borne system.

A typical Lear SCAN installation might involve the directional and air-speed indicating systems of an airplane, which together can show heading and distance traveled. The airplane is also tuned to two VHF radio stations which provide continuous "angle-angle" positioning data by their relative directions from the airplane. Such radio contact might, for example, be accomplished by two Lear Automatic Direction Finder instruments.

During the early part of a flight, errors inherent in the directional gyro system due to drift, and errors in the air-speed reading due to moving air masses, would accumulate in the form of an erroneous position indication. SCAN's first function would be to correct the air-borne system continuously to conform with radio information.

Far over the horizon, however, there will be a much greater volume of electronic disturbance coming into the radio receivers than valid signals. This "bad" information must be screened out so that only the good information will be used to correct the air-borne system to pinpoint accuracy. Each such correction, of course, modifies the history of the flight so as to improve continuously the screening process and also to provide the course made good and the distance and heading to target.

The criterion that is used for data acceptance from the outside can be physi-



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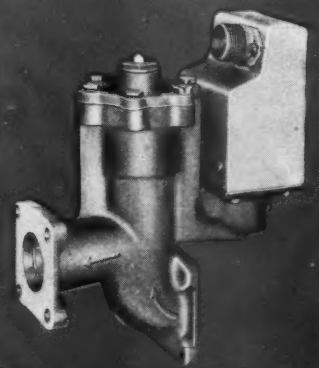
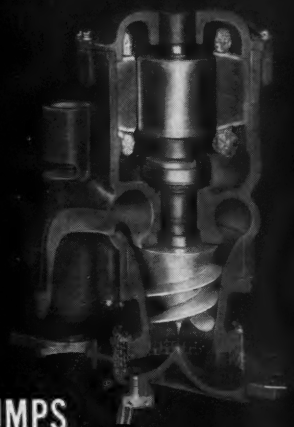


AIR VALVES

Types include solenoid pilot valves, pneumatically operated hot air valves, motor operated butterfly valves.



HY-$^{V}/_{L}$ FUEL PUMPS

High vapor liquid ratio fuel booster and transfer pumps. Outstanding performance . . . exceptional economy. Now flying on the F8U-1, F-101A, F-5D, B-52, the Regulus, the Navaho.

Architect's sketch of Lockheed Missile Systems Division's new plant in Sunnyvale, Calif., shows the Administration Building *(left, front)*, Engineering Building *(right, front)*, Cafeteria, and Manufacturing Building *(rear)*. The plant will be occupied by next summer. It adjoins Moffett Field.

cally represented as a circle surrounding the dead-reckoning indicated position of the aircraft. Since the circle represents the confidence limits that apply to the air-borne data system, it is known that the aircraft is somewhere within the circle. If radio data are being supplied at a reasonable rate (samples at intervals no longer than several minutes), then the circle is quite small. However, when outside data are interrupted, the circle grows with elapsed time. The Lear SCAN accounts for the expansion of this circle of possible error with time, in accordance with the known cumulative error probability of the air-borne system.

The Lear SCAN always carefully deliberates before accepting signals which are near the outer limits of this circle of credibility and in so doing simulates human reasoning process. Such signals have to be repeated several times before being incorporated in the voltage used to correct the air-borne system. Fewer repetitions of signals that are somewhat nearer the predicted position are demanded, and signals that are right in line are utilized instantly. In this manner, the navigational data are kept continuously corrected throughout each flight. Thus, when reception is renewed after an interruption, the Lear SCAN will somewhat reluctantly accept signals signifying wide departures from the indicated position, but, unless these prove convincingly persistent, they will be overridden quickly by the preponderance of signals representing the true new position.

In the event radio channels are completely saturated by enemy jamming, the airplane still can proceed with the inherent accuracy of the self-contained system through the remaining stages of flight or until good radio signals are again available.

• **Lockheed Aircraft Corporation . . .** Ground was broken in May for the Lockheed Missile Systems Division's new plant in Sunnyvale, Calif., on a 275-acre site adjacent to Moffett Field. The new facilities, scheduled for completion next summer, will supplement the company's present Missile Systems plant in Van Nuys, Calif. The four buildings to be constructed, all of modern, one-story design, will be an administration building of 48,000 sq.ft., an engineering building 96,000 sq.ft., a manufacturing building 96,000 sq.ft., and a cafeteria 20,000 sq.ft. The Administration Building, 240 by 200 ft., will have a large reception lobby featuring glass panels and a field-stone facing. The Manufacturing and Engineering Buildings, each 600 by 160 ft., will have lobbies with similar glass and field-stone exteriors. The Missile Systems Division is constructing research laboratories with 102,000 sq.ft. of floor space at Stanford University's industrial park in nearby Palo Alto. These laboratories will be completed this fall. . . . For test work on the prop-jet Electra air liner, Lockheed electronics engineers have developed what they believe to be the world's smallest television camera. It is 5 in. long, weighs $1^1/_2$ lbs., and has an 8-mm. lens. The TV camera will be attached to the outside of the plane to observe tufts in flight and also will be placed where it can see into inaccessible areas such as the inside of a landing-gear housing. If a problem is detected in flight, the plane can be maneuvered to maintain a desired test condition so that all characteristics can be studied immediately. There is no need to wait for movie film to be developed and then to make additional flights to gain more information. The TV camera has many uses in structural testing, where it permits a close-up view in situations that would be dangerous for an actual observer. . . . Lockheed's Georgia Division has opened an engineering office in St. Augustine, Fla. . . . Lockheed Aircraft Service, Inc., has moved from Burbank to Ontario, Calif.

• **Manning, Maxwell & Moore, Inc.,** of Stratford, Conn., has issued a bulletin on *Transmitting Potentiometers.*

• **Marquardt Aircraft Company . . .** William C. Foster, Executive Vice-President of Olin Mathieson Chemical Corporation, has been elected to the Board of Directors. He is a former Deputy Secretary of Defense.

• **The Glenn L. Martin Company** has been selected by the Air Force as the winner of a competition to develop a new experimental tactical bomber. A company announcement said Phase I of the development has already been completed. . . . Martin has been selected by the government of the Dominican Republic to design and build a nuclear-powered electrical generating plant near Ciudad Trujillo.

• **McDonnell Aircraft Corporation** is using an unusual facility for full-scale structural testing of missile components under extreme heat conditions which would be encountered at more than 5,000 m.p.h. A missile specimen 15 ft. long and 3 ft. in diameter can be tested at temperatures up to 1,000°F., and smaller structures can be subjected to tests at temperatures up to 1,500°F. McDonnell engineers investigated several systems of rapid heating based on a desired heating rate of 15°F. per sec. and finally adopted a radiant heating system utilizing quartz lamps and heat reflectors. This method allows wide flexibility to be obtained, since the number of lamps used and the distance between the missile specimen and the lamps can be adjusted to obtain a higher or lower rate of heating. The Physical Laboratory's power source was increased to 600 kw. This method of structural testing is believed closely to duplicate flight conditions by the simultaneous application of flight loads and very high temperatures to the basic structure.

• **Minneapolis-Honeywell Regulator Company . . .** More than 150 Navy transport and mapping planes will be equipped with automatic flight controls under a new R5D (DC-4) modification program extending over a period of several years. An altitude controller manufactured by the Aeronautical Division will be combined with the M-1 autopilot to enhance the ability of the automatic pilot for long flights. The M-H altitude controller, which already is being used on the F-100C, F-101, F-89, B-66, and B-36, is an aneroid pressure instrument that "feels" deviations in a plane's altitude by sensing changes in barometric pressure. It can detect a change of 5 ft. at an altitude of 40,000 ft. The controller, which weighs 9.2 lbs., continually signals the autopilot to bring the plane back to the desired altitude. . . . The MB-3 autopilot is being installed in the North American F-100D Super Sabre. In addition to stabilizing the plane at supersonic speeds, the MB-3 provides precise regulation of altitude and air speed and instantaneous response to guidance commands from navigational radar bombing and automatic fire control devices.

• **Norden-Ketay Corporation . . .** The Norden Laboratories, of White Plains, N.Y., has been elected to membership in the Radio Technical Commission for Aeronautics. . . . Perry R. Roehm, formerly Executive Vice-President, has been elected President of Norden-Ketay Corporation. He succeeded Morris F. Ketay, founder of the company, who retired as

Pictured below are four reasons why Rohr is world-famous as the builder of ready-to-install Pow-R-Pax for airplanes. In addition to the Lockheed Super G Constellation—Rohr builds the Pow-R-Pax for many other leading commercial and military planes including the Boeing KC-135, B-52, Douglas DC-7 and the Convair 440.

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1.062" Diam. x 1-45/64 long, weight 4 oz.

HIGH ACCURACY
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President but continues on the Board of Directors. . . . Norden-Ketay has issued three bulletins with specifications on its precision synchro resolvers, magnetic servoamplifiers, and gear head servomotor.

• **North American Aviation, Inc.** . . . The Missile Development Division, developer of the Chem-Mill process, is operating a pilot plant for chemical etching of steel, titanium, and aluminum alloys used in making aircraft parts. Although the purpose of the small plant is largely experimental, it is turning out parts for the SM-64 Navaho guided missile, which is under development at North American's Downey (Calif.) plant.

• **Northrop Aircraft, Inc.,** has established a facility at Holloman Air Force Base, N.M., for the use of its subsidiary, Radioplane Company. Radioplane Company conducts field tests of drone aircraft and guided missiles there. . . . Northrop's Anaheim (Calif.) plant, employing 1,400 persons, established a perfect safety record for 1955 in the National Safety Council's annual contest. Northrop's installation at the Air Force Missile Test Center, Cocoa, Fla., with 430 employees, also had a perfect score to tie for first place in the safety contest among smaller firms. . . . Robert R. Miller has been elevated to Vice-President and General Manager of Northrop. C. Hart Miller has been elected Vice-President for Administration. Richard R. Nolan has been named Vice-President in charge of Manufacturing.

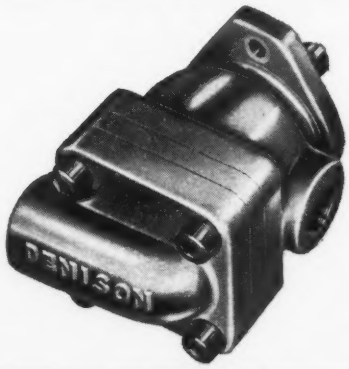
• **Pan American World Airways, Inc.** . . . One of the largest and fastest electronic data-processing machines has been installed in the Long Island City (N.Y.) office of Pan American to speed up the great volume of accounting work and the fantastically complex procedures of the international air line. The entire passenger-revenue accounting task, which previously required 4,000 hours of machine time each month, can now be done in 125 machine-hours. The machine also will be used to revise the company's entire program of inventory reserves and to provide statistics on cargo and passenger trends. . . . Pan American has added a fifth around-the-world flight to its schedules.

• **The Parker Appliance Company** . . . Floats of hard unicellular rubber sponge, fabricated to customer's specifications, are now being manufactured by the Rubber Products Division. Testing indicates the material is suitable for use in water, oil, gasoline and aviation fuels, and certain other liquids over a wide temperature range. It is lighter than cork, can withstand higher temperatures, resists fungus growth, needs no protective coating, maintains stable weight and volume, and does not become waterlogged. Unlike some metal floats, it does not fail as a result of vibration or puncture. It can be molded to shape, drilled, and machined. . . . Parker announces two new O-ring compounds, one resistant to aircraft fuel and the other to grease and oil.

• **Republic Aviation Corporation** is using closed-circuit television in building assembly jigs and fixtures. The television camera replaces the man behind the telescope. Now one man, watching the television screen, aligns the contour plate.

One Waldes Truarc Ring Saves a Pound in Weight Replaces Cast Retainer Plate and Four Screws

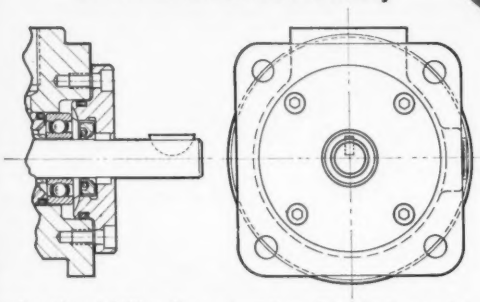
Denison Vane Type Pump/Motor



The Denison Engineering Company of Columbus, Ohio uses a Waldes Truarc Beveled Retaining Ring (Series 5002) in their pump/motor to achieve a simpler, lighter, more easily assembled unit and to cut both material costs and production time.

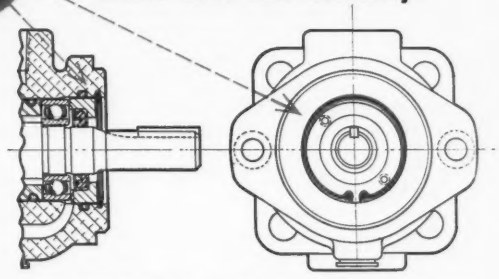
This vane-type power package operates as either a fluid pump or motor without alterations of any kind. Built for 2000 psi continuous duty, rugged construction was essential.

Shaft Seal Subassembly



Experimental Way: One cast retainer plate plus four socket head cap screws hold unit together. Assembly requires skilled labor, machinery, time-consuming careful adjustment.

Shaft Seal Subassembly



Truarc Way: Waldes Truarc beveled retaining ring (internal 5002) retains shaft and bearings, takes up accumulated tolerances rigidly, prevents leakage around shaft. Unit is one pound lighter. Assembly is quick and easy, more economical.

Wherever you now use machined shoulders, bolts, snap rings, or cotter pins, there's a Waldes Truarc Retaining Ring designed to do a better, more economical job. Truarc Rings are precision engineered, quick and easy to assemble and disassemble.

More than 5,000 stock-sizes of the different Truarc ring types available. Ninety stocking points throughout U. S. A. and Canada.

Find out what Waldes Truarc Retaining Rings can do for you toward reducing costs and improving your product. Send your blueprints to Waldes Truarc Engineers for individual attention without obligation.

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Ryan's proposed "Vertiplane" for the Army will be designed on the deflected-slipstream principle, with large, retractable wing flaps capable of diverting the thrust from two large propellers straight downward. This is an artist's sketch of the experimental VTOL plane.

The new method cuts time and cost sharply.

• **Ryan Aeronautical Company** has announced it will design and build for the Army a light VTOL aircraft to be called the "vertiplane." The new craft will achieve vertical take-off and landing by employing the deflected slipstream principle, using large propellers and double, retractable wing flaps extending far below and to the rear of the wing trailing edge. It will be a medium-speed plane for light passenger and cargo transportation and liaison work. The vertiplane will be capable of the same flight maneuvers now associated with helicopters, the company said, but it will be superior to rotary-winged aircraft in speed, range, altitude, and endurance. The experimental airplane will embody a conventional configuration with the exception that the wing incorporates large flaps located in such a way that the propeller slipstream can be deflected 90° downward during take-off, hovering, and landing. For transition into horizontal flight, the flaps will retract as the plane picks up forward speed and the slipstream then will flow horizontally. In landing, the pilot will make an approach under power with some flap deflection. Then, he will extend the flaps and add power until the touchdown is made at zero forward speed. The vertiplane remains in a level attitude during landing and take-off. It will be powered by a single gas turbine driving two propellers. . . . A new version of the Firebee jet drone missile, capable of operation at altitudes over 50,000 ft. and at high subsonic speeds, has been built by Ryan and is being flight-tested this summer at Holloman Air Development Center, N.M. The original Q-2A target drones, now in operational use, were designed to fly up to 40,000 ft. The new XQ-2B's have an improved control system incorporating automatic climb and dive features and glide control. Their wing area is one third larger. A Fairchild FT-101-D-1 turbojet engine with 1,000 lbs. thrust powers the new drones.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation . . .** Electronic engine analyzers will be widely used by the Air Force in test cells at overhaul centers across the nation and in certain passenger aircraft, according to a company announcement. Ground portable analyzers are being manufactured for the Air Materiel Command and air-borne analyzer systems for the Military Air Transport Service. The analyzer detects and indicates on a cathode-ray screen disorders in spark plugs, magneto, condenser, coil, and ignition wiring. It also discovers improper valve adjustment, warped or sticking valves, broken valve springs, loose guides, bent push rods, and piston slap. The malfunctions can be discovered and corrected in early stages, thus preventing accidents in the air. Maintenance time is reduced drastically. . . . Sperry, which has been conducting extensive research into the problems connected with turbine engine controls, has developed variable geometry controls for an advanced supersonic fighter engine and a shock positioner control system for a ram-jet missile. Shock positioners are a means of achieving maximum performance in a jet engine by maintaining a pressure wave at a predetermined point in the air inlet nozzle through precise fuel-flow control.

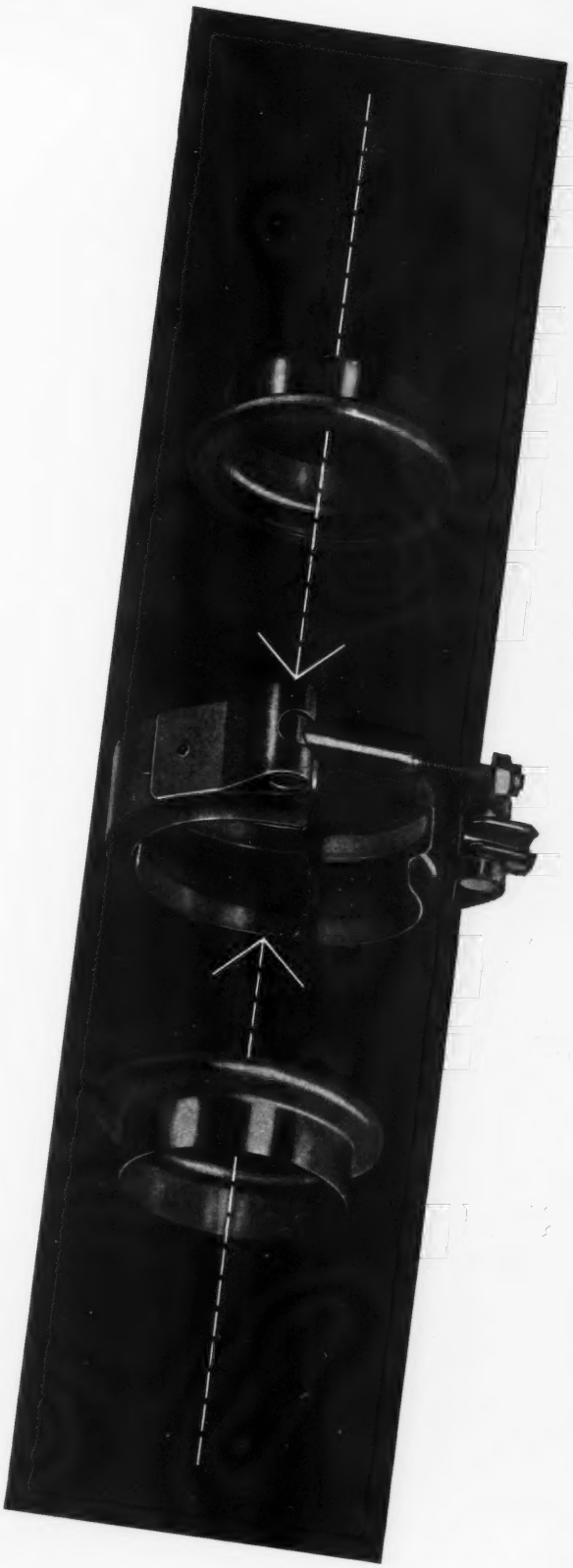
• **Sturgess, Inc.,** of Glendale, Calif., has changed its name to Pacific Scientific Aeroproducts.

• **Thompson Products, Inc.,** is operating for the Navy Bureau of Aeronautics a new laboratory for testing turbojet and turboprop engine parts and assemblies in engines with thrust ratings up to 40,000 lbs. Known as the U.S. Naval Industrial Reserve Aircraft Component Testing Plant, it is located 25 miles northeast of Cleveland, on a 90-acre tract on the shore of Lake Erie. The laboratory, which cost $1,400,000, has twin test cells 24 ft. wide, 24 ft. high, and 211 ft. long, encased in reinforced concrete walls a foot thick. There is also a high-temperature spin pit for testing turbo power-plant rotating elements and a test facility for very high temperature fuel.

• **Vertol Aircraft Corporation** is working on the design and development of a "tilt-wing," turbine-powered VTOL research aircraft for the Army. The company said it will utilize the "flying test bed" approach, which will permit the tilt-wing VTOL design to be explored with a relatively inexpensive aircraft in a matter of months, instead of taking years to design and construct a costly prototype. The airplane will be powered by a single turboprop engine geared to two rotor-propellers mounted on the wing tips. In take-off and in hovering flight, the tiltable wing is in the vertical position and the large rotor-

Vertol's research on a VTOL aircraft using the tilting-wing principle may eventually lead to Army vehicles such as this utility type shown operating from an unprepared area in the jungle. Such a craft would fly much faster than a helicopter and would contribute to the mobility of Army forces.

What's special about these couplings?



Look at the newest couplings for jet aircraft bleed air ductwork! Connect them, disconnect them—again and again—they remain tight and dependable. Trouble-free performance is a result of metal to metal seal, with no secondary sealing devices or compounds. No loose parts to get lost or damaged.

Janitrol couplings save up to 40% in weight over conventional designs, yet they're designed for continuous use at 250 psi at 750°F. To make installation easy, clamp tightens on latching side; quick connects and disconnects can be made in hard-to-reach locations! Lock nut torque is only 35 in. lbs.

They withstand corrosion, pressures, temperatures, surges, misalignment, and vibration. Maximum design leakage is .01 cfm per inch of duct diameter.

Seven sizes available now, from 1½" to 4"; special sizes and designs made to order.

Janitrol *aircraft* couplings are a product of experience in aircraft air handling dating back to World War II. For full details and specification data write or phone your nearest Janitrol representative.

Janitrol Aircraft-Automotive Division, Surface Combustion Corporation, Columbus 16, Ohio . . . District Engineering Offices: Washington, D. C., Philadelphia, Columbus, Ft. Worth, Hollywood.

COMBUSTION SYSTEMS · HEAT EXCHANGERS · PNEUMATIC CONTROLS

Janitrol

propellers provide vertical thrust, as in the helicopter. For cruising and high-speed flight, the wing is in the normal horizontal position. The transition from vertical lift to forward flight is accomplished by tilting the wing-propeller combination forward. Thus, in forward flight, the wing provides the lift and the rotor-propellers provide the thrust.

• **Vickers Incorporated** has reorganized its Engineering Division to permit accelerated research and development programs in ever-broadening areas of hydraulic system application. The Division is composed of five operating departments and an administrative department. The Research and Development Department combines all groups working on basic research problems in hydraulic and related fields. Design and engineering for each of Vickers' principal product lines is handled by a separate department (two departments in the case of aircraft), each headed by a chief engineer responsible for products and complete systems in that field. These four departments cover industrial, automation, and marine products; ground mobile products; air-borne products (Detroit); and air-borne products (El Segundo). . . . Vickers announces a new line of hydraulic-powered electrical power packages for air-borne installations. The unit consists of a permanent-magnet, 400-cycle type of a.c. generator directly driven by a flange-mounted Vickers constant-speed oil-hydraulic motor. The motor is powered by flow available in the existing aircraft hydraulic system. The units are available in six sizes for 0.5 to 3.0 kva. output. They weigh from 7 to 19 lbs. Applications for this development are the powering of copilot instrumentation in multiengined aircraft and supplying controlled-frequency a.c. power in emergencies when the only source of power in the airplane is a ram-air turbine-driven hydraulic pump. . . . Owen C. Davis, formerly Controller, has been elected Treasurer of Vickers Incorporated.

• **Weber Aircraft Corporation,** Burbank, Calif., is distributing reprints of two technical articles on its electronic analog computers. One describes its Toggle-Switch Programmed Computer. The other article is entitled "High Power from Miniature Tubes."

• **Westinghouse Electric Corporation . . .** During the recent enlargement of O'Hare Field, Chicago, to make it suitable for commercial as well as military operations, the control tower was moved to a better location 6,000 ft. across the field. Westinghouse installed remote-control equipment for the field's lighting system, making it unnecessary to relocate more than a mile of underground conduit. A telephone circuit links the push buttons in the control tower with the old controls on the other side of the field. . . . A. M. Kennedy, Jr., and F. M. Sloan have been elected Vice-Presidents of Westinghouse Electric Corporation.

IAS SECTIONS

Meet Your Section Chairman

Earl R. Hinz

San Diego Section

Earl Robert Hinz, Chief of Systems and Controls, Engineering Division, Ryan Aeronautical Company, is Chairman of the San Diego Section for 1955–1956.

Earl was born in Minneapolis, on July 25, 1919. After graduating from high school, he entered the University of Minnesota in 1938. He had to leave school in December, 1940, when he was called into the U.S. Marine Corps.

In 1942 he was commissioned an ensign in the U.S. Naval Reserve, and during the following war years he served at NAS, Pearl Harbor, and NAS, North Island, San Diego. In 1944 he was transferred to the Navy Bureau of Aeronautics in the Airborne Equipment Branch and remained there until he was separated in November, 1945. Earl has remained active in the Naval Reserve and now holds the rank of lieutenant commander.

Upon separation from the service, Earl returned to the University of Minnesota and received his Bachelor's degree in Aeronautical Engineering in 1947. After a summer with the Curtiss-Wright Corporation, he returned to school and obtained his Master of Science degree the following year. From 1948 to 1950 he was Associate Scientist, Rosemount Aeronautical Laboratory, University of Minnesota, and also an instructor in aeronautical engineering. During this time he became a registered aeronautical engineer in the state of Minnesota.

In 1950, Earl moved to San Diego and joined Convair's Aerodynamics Group. As a Senior Aerodynamics Engineer at Convair, he was responsible for much of the aerodynamics work on the F-102.

He moved across the field to Ryan in 1953 and has progressed from Senior Aerodynamics Engineer to Research Group Engineer in charge of Stability and Control and, in May of this year, to his present position of Unit Chief, Systems and Controls, where he is in charge of all systems and controls analysis functions on both aircraft and missile projects.

During the time Earl has been in San Diego he has retained an interest in teaching, serving as a lecturer in engineering for the University of California's off-campus graduate program.

Earl has been active in IAS work since he first came to San Diego, having held four major offices prior to his election as Chairman. He is an Associate Fellow of the Institute and this year is also serving as General Chairman of the 1956 National Turbine-Powered Air Transportation Meeting.

Earl and his wife, who were high school sweethearts, live with their son in La Jolla. In addition to his IAS and teaching work, he participates in many recreational diversions such as square dancing, skin diving, tennis, and camping.

Soviet Education

Boston Section

The annual meeting was held May 14 in Nahant, with almost 200 members and guests attending. After dinner, Chairman Robert Halfman introduced the newly elected officers for 1956–1957: Chairman Edward L. Dashefsky, Vice-Chairman John B. Tucker, Secretary Daniel J. Fink, and Treasurer Eugene E. Larrabee.

Raymond L. Bisplinghoff, Professor of Aeronautical Engineering at Massachusetts Institute of Technology, was Moderator for a discussion of engineering education in the Soviet Union. The panel members were Alexander Korol of the Center for International Studies, M.I.T.; Nicholas DeWitt of the Russian Research Center, Harvard University; and Leon Trilling of the Aeronautical Engineering Department of M.I.T. Mr. Korol described the Russian elementary and secondary school system, Mr. DeWitt presented a general picture of Russian engineering education, and Professor Trilling dealt specifically with aeronautical engineering education.

Mr. Korol pointed out that the Soviet system of secondary education shows features of American, European, and prerevolutionary Russian educational patterns combined into uniquely Soviet forms and integrated for the indoctrination and training of workers for the state economy.

In common with the American tradition in public education, the Soviet

system is designed for mass education. In common with the general European practice, Soviet schools have a rigidly fixed and uniform curriculum in all schools of general education, the methods of instruction are formal and authoritarian, and the academic demands made upon the student are rigorous. From prerevolutionary Russia the Soviet school has resurrected many features of the tsarist state-operated schools, such as the centralized bureaucratic control of the schools, the quasi-military, strict discipline, and the uniforms which students must wear in and out of school.

The central component of the Soviet educational system is the ten-year school, which combines elementary, middle, and secondary education and is roughly comparable to our college preparatory high school. Soviet children start their school 1 year later (at age 7) and finish 1 year earlier (at age 17) than do our high school graduates.

Not all who enter the system at age 7 succeed in completing the ten-year school. At the end of the elementary schooling, there is a more or less irrevocable siphoning-off from the main educational stream into the ranks of common and semiskilled labor and, after the completion of the seventh grade, into the ranks of skilled and subprofessional labor via additional training in specialized schools such as "technicums." Perhaps not more than 20 per cent complete the tenth grade.

The curriculum completed by the ten-year school graduates (currently numbering about 1,000,000 per year) is heavily concentrated on science (including 5 years of physics) and mathematics (including algebra, plane and solid geometry, and trigonometry). Most of the ten-year school graduates apply for admission to schools of higher education, but, on the basis of competitive examinations against a fixed quota of vacancies, only about four out of ten applicants are admitted.

Mr. DeWitt began by emphasizing that higher education is used as a tool in the hands of the state. It is desirable from the Soviet citizen's point of view to go on for higher education. As a student, he pays no tuition and is in fact paid up to two thirds of what he would receive as an industrial wage. If he is unusually able, he will receive additional scholarships and, as a student, will be deferred from military service. If he is an exceptional student, he may be completely exempted from military obligations.

A school certificate carries prestige in the Soviet state, perhaps in some measure because of the fact that the population is not long removed from a system of little public education. Students who enter the Soviet higher education system are of unquestioned ability in view

Is your Jet Engine RPM Measurement Accurate???

The NEW B&H Instrument

TAKCAL

• COMPACT
• LIGHT
• RUGGED

• • • Reads Jet Engine Speed to Guaranteed Accuracy of 10 RPM in 10,000 RPM (±0.1%)

Checks Tachometer System

Adapts to any Frequency Problem

The inter-relation of RPM to efficiency and thrust in jet engines is fundamental. Proper adjustments for maximum thrust, engine life and safety of operation can be made only upon accuracy of instrumentation.

The new B&H TAKCAL incorporates a refinement of the frequency meter principle. It operates in the low (0 to 1000 cps) range, reading the frequency of the tachometer generator on a scale calibrated in percent RPM corresponding to the engine's RPM. In addition, the TAKCAL checks the tach system. The TAKCAL circuit and tachometer are parallel so that readings can be made simultaneously to determine the accuracy (or inaccuracy) of the aircraft's tach system. The TAKCAL operates during the engine run to properly set up engine controls for maximum economy and safety.

The TAKCAL's component parts are identical with those used in the J-Model JETCAL Analyzer. They are here assembled as a separate unit tester and for use with all earlier models of the JETCAL Tester.

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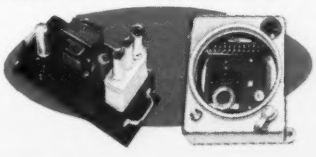

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of the competition they must face to be admitted and to graduate. In the elementary and secondary school system, only about 200 out of each 1,000 accepted 10 years previously succeeded in graduating from the tenth grade in 1955.

Admission to engineering institutes and universities is by entrance examination, and only one quarter of those who apply are accepted. In addition to technical competence, candidates for higher education are also subject to political screening. At the outset of his engineering course, which lasts $5^1/_2$ years, the applicant has his choice of the field he will enter. However, once having made this choice, he is not free to switch to another field.

There are 762 institutions of higher learning in the U.S.S.R., of which 737 are residential schools. Total enrollment is 1,850,000. The engineering schools account for one third of this total, or about 650,000 students. Of these 737 higher educational establishments, 33 are universities and 188 are resident engineering institutes, the latter having 450,000 resident students.

The engineering institutes are not organized into departments of mechanical, civil, electrical, aeronautical engineering and the like, but vertically by industries. Thus an aeronautical institute will be concerned with all fields and subjects which are related to the production of aircraft. In the engineering institutes, there are 760 specialties which may be pursued by the students. The length of the engineering course is $5^1/_2$ years, during which the student receives 5,200 to 5,500 hours of instruction, as compared with 3,700 to 4,000 hours (normally) in this country. Generally speaking, the extra hours go into the specialization field which the student is pursuing. The distribution of the student's time, by per cent, is as follows:

6–8 %	political subjects
26–30	general science
25–33	general engineering
22–28	special engineering

The engineering student's work load is heavy, ranging between 60 and 90 hours per week. During his academic career, he takes 40 examinations, attends three industrial practice sessions at factories, and prepares a thesis. Out of each 100 who enter this higher education system, 60 survive. Mr. DeWitt closed his presentation by pointing out the very large growth of education in science and engineering in the U.S.S.R. He said that, in the past 25 years, 1,000,000 teachers have been produced by their universities and that, of this number, 350,000 are science teachers. Certainly the number of our science teachers compares most unfavorably with this, aside from any considerations of quality.

Professor Trilling dealt with aeronautical engineering education and indicated that the engineering institutes where this subject is taught are closely linked to the Russian aeronautical industry. Indeed, the same men who establish the subject matter and teaching policies also have responsibilities in the design of new aircraft and in the Ministry of Production.

There are 16,000 resident aeronautical engineering students in the U.S.S.R. as compared with our 8,000. Their curriculum is in a rough way comparable to a 5-year Master's degree program at M.I.T., although they tend to sit through more lecture hours than do our students. They have the same specialties of aerodynamics, structures, propulsion, and automatic control. In the field of aircraft design, the Russians have 9,000 students as contrasted with our 6,000. Comprehensive textbooks are used in teaching. These are complete with respect to the present state of the art and therefore must be, and are, frequently rewritten.

At the end of the $5^1/_2$-year period, the graduate is expected to be immediately useful in the industry and is given no on-the-job training. As to his choice of jobs, he is given two or three possibilities from which he must choose, although—in the case of superior students—job assignments may be prearranged as a result of the contacts made during the student's three industrial practice sessions.

The aeronautical industry is controlled by a relatively small number of men, regarded as first class, who are responsible vertically for all phases of aircraft production. Since communication is good among such a small number, the flexibility of such a system is excellent. As the technical institutes train engineers, the universities produce researchers and teachers. Generally speaking, the university graduate becomes a good applied mathematician and is deployed as a member of a task force against the current scientific bottleneck. Thus the university graduates, strong in mathematics, serve as roving theoreticians. In the field of fluid mechanics, they solved the problems of transonic flow and supersonic flow independently of our own solutions of these problems.

Professor Trilling indicated that perhaps Soviet dependence on such a small number of leaders might prove to be dangerous for them, since there may be inadequate safeguarding against major mistakes. He cited a German view that Russian engineers are competent but narrow and weak at making decisions. Could it be that the rigidity of their educational system suppresses any latent ability to make such decisions?

In response to a question as to the effect of the heavy academic work load on the morale of the students, Mr. Korol pointed out that only their physical endurance was limiting. When asked about the effect on student enthusiasm of the recent de-Stalinization policy, Professor Trilling pointed out that enthusiasm among students is kept high by "fight talks" centered around beating the United States. He felt that changes in the party line must produce loss of enthusiasm, perhaps even cynicism, and an attitude of doing the minimum and "working the angles." This, of course, would lead to a loss of creativity.

Mr. DeWitt was asked whether Soviet youngsters had opportunity to acquire mechanical know-how in their everyday life, as our boys do. He replied that there was less day-to-day contact with mechanical and electrical equipment but more organized activity for their youth where such contact is deliberately sought. The next question asked was whether there is discernible any trend toward broader education in the U.S.S.R., and all three panelists responded to this. The consensus of their remarks was that there is a conflict of interest between educators and production people, the former favoring broader education, the latter wanting immediately useful products. It was felt that the "immediately useful" philosophy would undoubtedly prevail, since the key production people are also in charge of the educational policy.

Professor Trilling replied to a question on research and development activities by citing the field of fluid mechanics, in which he thought the Soviets and ourselves came off with equal honors. On the development side, he pointed to their high-thrust jet engines and their jet bombers as unquestioned evidence of their ability to develop and produce aircraft.

It also appears that Russian scientists and engineers make extensive use of our technical publications, as evidenced by their comprehensive abstracts of technical papers, as well as their thorough cataloging system for foreign publications. The final question asked was whether there might not be a considerable gap between the scientists engaged in studying fundamental problems and those engineers who apply the results of such research to the design of aircraft, a case in point being the fact that there appears to be no Russian aircraft conforming to the area rule. Professor Trilling agreed that such might be true because of the fact that their design and production establishments are physically separated, and that this might tend to slow down the adoption of new features. On the other hand, leadership by a relatively small number of people, plus frequently revised textbooks, works toward closing this gap, and hence one cannot come to a definite conclusion.

WALTER MCKAY, *Secretary*

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Cleveland-Akron Section

Bruce T. Lundin, Chief of the Engine Research Division, Lewis Flight Propulsion Laboratory, NACA, has been elected Chairman of the Cleveland-Akron Section for 1956–1957.

Howard F. Powders, of the American Steel and Wire Division, United States Steel Corporation, was elected Vice-Chairman for Cleveland. Calvin M. Bolster, of the General Tire and Rubber Company, is the new Vice-Chairman for Akron.

John C. Evvard, of the NACA, was chosen Secretary and William A. Fleming, of the NACA, Treasurer.

The new Advisory Board consists of Karl Arnstein, Raymond E. Bolz, John W. Ebert, Jr., James O. Gibson, Eugene J. Manganiello, Abe Silverstein, Edward R. Sharp, and Charles H. Smith, Jr.

WILLIAM A. FLEMING, *Secretary*

Dayton Section

Fifty members and guests met on April 19 to hear a discussion by J. Edward Taylor, of Thompson Products, Inc., on the subject, "Trends in Aircraft Accessories." Mr. Taylor's presentation dealt with the problem of fuel systems accessories in supersonic aircraft. He considered first the effect of high temperatures resulting from supersonic speeds on the fuel and what could be done to the fuel to alleviate problems, and then discussed the equipment and what must be done in general with that equipment.

Mr. Taylor pointed out that, under the very high temperatures of supersonic flight, fuel can crack, gum, polymerize, ignite spontaneously, vaporize and be lost, or vaporize and be absorbed, to be released later in some particularly undesirable location; and, of course, heat can ruin elastomers in the system. Special fuels can be developed with superior thermal resistance, providing, of course, it is known just what composition will provide this superior resistance. At this instant, only research programs are being engaged in to determine these criteria, and much work remains to be done. A great deal can be done by way of accessory component design to reduce their size through much higher-speed, higher-specific-volume pumps, simplification, and miniaturization. Obviously, the fuel available in an aircraft presents a vast heat sink which should be used for cooling other components, and there is optimism that ways will be found to use this asset.

In all likelihood, the solution to the fuel system problem and supersonic flight will be solved through a combination of specialized fuels and specialized fuel system components.

The Dayton Section has elected the following officers for next year: Chairman, Gunther R. Graetzer; Vice-Chairman, T. J. Keating; Secretary, Walter E. Stanger; and Treasurer, Frank E. Carroll.

W. Donald Dodd, Jr., Past Chairman, was named Representative to the Nominating Committee for Area Councilors. The Council members are Warren Joy, Alfred B. Longyear, William Lankin, Barton E. Day, and John S. McCollom.

T. J. KEATING, *Secretary*

Satellite

Hampton Roads Section

A joint meeting with the Engineers Club of the Virginia Peninsula on May 21 heard Capt. Alfred B. Metzger, Deputy Chief of Naval Research, speak on "The Vanguard Satellite Project."

Captain Metzger, an Associate Fellow of the IAS, outlined the previous work by the Office of Naval Research in high-altitude rockets which led to the selection of that agency to manage the technical program of Project Vanguard. He described the three objectives of the program: to put an object into an orbit, to prove that the orbit has been established, and to gather appropriate scientific information. Some colored slides illustrated the rocket and its flight path.

The rocket will be fired from the long-range missile test center at Patrick Air Force Base, Fla., The azimuth must be south of east by an angle at least as great as the latitude of Patrick AFB, which is 29° north. The rotation of the earth produces an eastward velocity at the launching site of 1,340 ft. per sec., a valuable addition to the speed of the rocket.

The Vanguard satellite will be launched by a three-stage propulsion system. The first two stages will be liquid-fueled rockets. The third stage will be a solid-fuel rocket which Captain Metzger said would be constructed by the Allegheny Ballistics Laboratory and the Grand Central Aircraft Company. The first and second stages will be stabilized by the movement of their motors on gimbals, and the third stage will be spin-stabilized. The guidance system necessary to direct the movement of the first- and second-stage motors will be contained in the second stage. The guidance system will also time the delay separation of the second stage and impart a spin to the third stage.

The complete configuration will be 72 ft. long and 45 in. in diameter and will weigh 11 tons gross. The first stage will burn out and separate at an altitude of 36 miles and an elevation of 45° and will fall into the ocean at a range of 230 miles. The second stage will burn out at an altitude of 140 miles when one half of the final velocity of 25,000 ft. per sec. has been reached. The second and third stages and the satellite will coast to an altitude of 300 miles, covering a surface distance of 700 miles as they climb. The second-stage guidance mechanism will impart a spin to the third stage and direct it into the orbit. The third stage will accelerate the satellite to orbital velocity and will separate from the satellite, but the tenuousness of the air will permit it to orbit close behind the satellite.

The satellite will complete a revolution of the earth every 90 min. and will cross the same latitude 22° farther west with each revolution. The small transmitter in the satellite will operate only on command of the tracking stations spaced around the earth for the Vanguard Project. Tubes will be used in the transmitter in spite of a slight weight penalty that transistors could eliminate because of the more advanced state of art of constructing tube-operated equipment. Power output will be 10 to 15 milliwatts on a frequency of 108 mc.

Captain Metzger stated that plans will soon appear in amateur radio publications showing the construction of a tracking receiver. He said that hams will be encouraged to build these receivers to add to the number of measurements of the position of the satellite.

JAMES HOLLINGER
Publicity Chairman

Indianapolis Section

"Air Force Aims in Aeronautical Development" was the topic of an address delivered by Brig. Gen. Marvin C. Demler, USAF, at the annual meeting April 16. An authority on planning processes, General Demler is Deputy Commander for Research and Development, Headquarters, Air Research and Development Command, U.S. Air Force. He was introduced by Dimitrius Gerdan, Director of Engineering, Allison Division, General Motors Corporation.

Illustrating his speech with slides, General Demler compared such things as speed, standard of living, and manufactured power versus time in years. The trend of the curves was approximately that of an exponential curve where the curve is currently achieving a steep slope. Extrapolating these curves leads to predictable design speeds required in the years of the near future.

Another interesting facet of development that was vividly portrayed by curves was the rate at which specific fuel consumption and weight in turbine-type engines has changed in the last few years. The curve apparently is becoming asymptotic to the abscissa, and further reductions in both items will become harder to achieve.

"Technical breakthroughs" were keynoted as primary targets which must be

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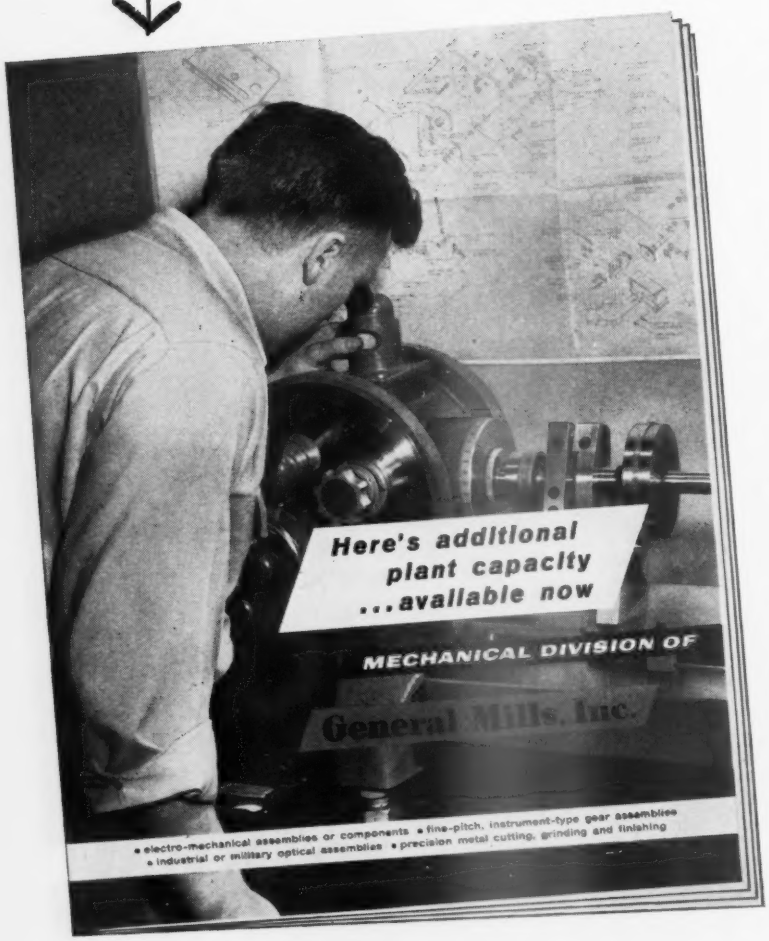
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strived for in the future in order to maintain technical equivalence with competitive air powers. Excellent examples cited as recent technical breakthroughs were boundary-layer control, the fuselage area rule, and nuclear power plants. General Demler challenged his listeners to contribute to such breakthroughs, saying that the impetus for technical advancement may come from many directions.

The following officers have been elected for 1956–1957: Chairman, Robert E. Saff; Vice-Chairman, R. C. Binder; Secretary, James A. Duff; and Treasurer, James A. Anderson.

E. G. Delaney, P. E. Stanley, and R. S. Hall were elected to the Board of Directors. The retiring Chairman and Vice-Chairman, P. N. Bright and M. J. Zucrow, are ex-officio members. E. M. Howard was named Representative on the Nominating Committee for Area Councilors.

H. E. Helms
Publicity Chairman

Los Angeles Section

The March dinner meeting featured a talk by Philip A. Colman, FIAS, Chief Preliminary Design Engineer, Lockheed Aircraft Corporation, on "Development of the Lockheed Electra."

Mr. Colman noted that the question of choice between a turbine engine driving a propeller and a turbojet for a commercial airplane is not immediately obvious. However, a comparison between reciprocating and turbine engines for commercial airplanes indicates the turbines to be superior on every count. Turbine engines will power tomorrow's transports, but which kind—pure jet or with propeller? The important parameters for the design of a commercial airplane are operating speed and operating economy.

The minimum cost for medium-range operation appears of the order of 425 m.p.h. speed range for the turboprop and 525 m.p.h. speed range for the jet. Thus the jet airplane has a basic 100 m.p.h. speed advantage to compensate for its 20 per cent higher operating cost. The choice between prop and jet must therefore depend on the value given to the speed differential.

The following factors make the turbopropeller more economical:

(1) A turbine engine which has a static jet thrust of 2,000 lbs. can be geared to a propeller and produce 10,000 lbs.

(2) A jet airplane must be at least 100 m.p.h. faster than a turboprop to approach the minimum 20 per cent differential in operating costs and thus requires a highly swept thin wing.

(3) The wing-design requirements for high-speed flight result in an empty

weight 35 per cent higher for a turbojet.

(4) The turbojet wing is less efficient for maximum lifting capacity, and a considerably larger wing is required.

(5) The jet airplane will require at least 50 per cent more fuel, plus twice the reserve fuel.

(6) The structural weight of the jet is greater, and therefore the basic price must also be greater.

These factors have led the air lines to conclude that the jet is optimum for long-range use, and the turboprop is optimum for short-range.

The Electra is the idealized turboprop configuration for the short-range operation. For its longest optimized design range of Chicago to San Francisco, its take-off gross weight for maximum pay load of 20,600 lbs. is 108,000 lbs. It utilizes four Allison T-56 engines, driving 13.5-ft. diameter propellers, giving it a cruising speed for its initial operation in late 1958 of the order of 405 m.p.h. The Electra is designed to have a maximum range sufficient for operation over a 2,500-mile route against 40 m.p.h. headwinds and with adequate reserves.

It may make several stops without refueling. The Electra can carry 85 passengers in five-abreast seating. The passengers plus baggage plus cargo give a maximum design pay load of 20,600 lbs. The basic design weight (empty) of the airplane is 53,993 lbs.

The wing area is 1,300 sq.ft. with an aspect ratio of 7.5. It has an average thickness of 13 per cent and an ultimate design Mach Number of 0.8. The thin wing allows for stretch for future power plants which will ultimately give the Electra cruising speeds in the order of 470 m.p.h.

The fuselage has a straight, constant section from just behind the cockpit to the lounge area. This is possible because the design requirement for this airplane is one for maximum utilization and minimum size. The fuselage has an inside diameter of 128 in. and five-abreast seating, with seat and aisle widths equal to those of current Constellation and DC-7 airplanes. The airplane contains two loading doors, one forward and one aft of the wing. The forward door contains an integral stairway.

The airplane is designed for both passenger carry-on baggage and checked baggage. Just aft and across from the passenger entrance are areas for the stowage of carry-on baggage. In addition, in the most forward and most aft areas under the floor are spaces for baggage and cargo.

The Allison T-56 turboprop delivers 3,750 equivalent s.hp. with a cruising specific fuel consumption of 0.467 lb./e.s.hp./hour. The engine is a constant-speed type, which means it has one r.p.m. for all flight conditions.

An analysis of Eastern Air Lines traffic shows that, for 90 per cent of the cumulative daily flights, the Electra will have a weight no greater than 90,000 lbs. for take-off with the 18,000-lb. pay load. On a standard-temperature day, the Electra requires 4,590 ft. for take-off. The normal landing weight for 18,000 lbs. of pay load is 83,000 lbs., and the airport requirement is 4,850 ft.; 92 per cent of all the flights can be completed with full passengers in the five-abreast version, plus passengers in the lounge if desired.

Cruise speed related to actual operations shows that, on 50 per cent of the flights with maximum pay load, the cruise speed will be 406 m.p.h. or greater, and, on 90 per cent of the flights, it will be 400 m.p.h. or greater. It should be noted that these speeds will be increased with the higher-powered engines at a later date.

Operating costs of the Electra with a standard interior are in a range of 1.2 cents per seat-mile. The DC-6B, which is 90 m.p.h. slower, has an operating cost that is 35 per cent higher. On a four-abreast seating basis, regardless of fuselage width, the Electra is 10 per cent better. The DC-7 is 45 m.p.h. slower than the Electra. With comparable passenger comfort, the Electra is 50 per cent cheaper per seat-mile.

The design range for optimizing the Electra was the area from 750 to 1,850 miles. However, the basic design has capabilities of flying considerably farther and can carry 20,600 lbs. 2,420 miles under zero wind conditions at a block speed of 361 m.p.h. The Electra is pressurized for operation at a maximum cruising altitude of 30,000 ft. This is a relatively low altitude compared to that for the long-range jet transports. However, it is the maximum required and eliminates some of the problems which must be faced for the long-range jet transports. It is below the altitude at which serious consequences can result from loss of pressure prior to an emergency descent. For the medium ranges, cruise altitudes from 17,000 to 28,000 ft. may be chosen with a negligible difference in block speed and less than 1 per cent difference in direct operating cost. For a 100-mile flight, the take-off, climb, and subsequent descent from any altitude from 5,000 to 17,000 ft. will not markedly change speeds or costs in an air-line operation.

The Electra design was specified and left the Preliminary Design Division of the Lockheed Corporation in September, 1955. The airplane is to fly November 1, 1957. Two airplanes each are to be delivered to Eastern Air Lines and to American Airlines with license August 1, 1958.

R. G. FULLER, *Secretary*

New York Section

About 250 members and guests visited Brookhaven National Laboratory of the Atomic Energy Commission at Upton, Long Island, on May 12.

After an introductory talk by H. B. Hansteen, the visitors were taken to the various facilities in buses. Guides and laboratory chiefs explained the intricacies of nuclear physics and engineering.

Probably the most interesting installations visited were the nuclear reactor and the cosmotron. The former is an atomic pile much like those used for power production in the commercial electric centers now under construction in various parts of the country. The same kind of generator is also used in the submarine and airplane power plants of the present and the near future. Although quite large, the nuclear reactor does not appear too different from an ordinary turboelectric power plant when viewed by the unitiated observer.

The cosmotron is not a machine but a piece of laboratory equipment on a gigantic scale. In it, minute masses are accelerated to velocities equal to about 98 per cent of the velocity of light. A visit to the hot chemical laboratory and to the meteorological installation rounded out the technical part of the program.

NICHOLAS J. HOFF
Secretary-Treasurer

San Diego Section

Meetings

A paper on "The Producibility Barrier" was presented by Fred Monahan, Coordinator of Manufacturing Research and Development, Convair, San Diego, at the May 24 meeting in the Institute Building.

Mr. Monahan spoke of the impact of future aircraft design upon the country's ability to produce. He also emphasized the need for accelerated effort in developing new materials, methods, and processes. New production techniques were discussed, and he indicated areas where further techniques must be developed. As a part of his presentation, Mr. Monahan showed a movie which demonstrated some of the new production techniques for forming, handling, milling, etc. Mr. Monahan closed his talk with the thought that producibility is now behind design and that a great need exists for research and development work in the field of producibility as soon as design is initiated.

▶ "The Navy's Aircraft Maintenance Problems" was the subject of the Technical Meeting held on May 8. The paper was presented jointly by Capt. Paul J. Burr, Aircraft Materiel Officer for the Commander, Air Force, Pacific Fleet; Comdr. Dean H. Swain, Aircraft Main-

tenance Officer; and Lt. Comdr. R. T. Rhees, Aircraft Maintenance Work Load Officer. Captain Burr started the meeting by discussing maintenance problems in general and the problems of scheduling modifications to keep all aircraft up to date. He particularly emphasized the Navy's present program of reducing aircraft time in storage and overhaul in order that the Navy may get more operational service life in fewer calendar years. Lieutenant Commander Rhees stressed the importance of incorporating maintenance improvements while aircraft are in the mock-up stage. He indicated that the Navy is placing a great deal of emphasis on this procedure. Commander Swain discussed the maintenance problems in fleet operations. He described the problem of performing maintenance on a congested carrier with a heaving, rolling deck.

Committee Activities

The Membership Committee, under Chairman John Hopkins, is doing an excellent job. In September, 1955, the San Diego Section had 286 members; as of June 1, it had 323. This steady growth has occurred only because of the efforts of the Membership Committee and of the members at large in selling the advantages of belonging to the Institute.

The following methods are used to help promote membership:

(1) Meeting rosters are reviewed regularly for guests' names, and letters are sent to these guests inviting them to consider membership.

(2) Area representatives at the various plants and aeronautical facilities serve both on the Membership Committee and on the ticket sales activities. In this way they are able to keep up to date on new people coming into the area.

(3) A membership chart, including outstanding applications, is displayed at each meeting. Guests are able to appreciate in this way the size of the Section and the current growth, and this has been found to encourage prospective members.

(4) The Student Activities Committee is instrumental in interesting students in membership, and this, it is found, generally furthers their interest after graduation.

R. A. FUHRMAN
Corresponding Secretary

Seattle Section

At the May 23 meeting, held in the Sand Point Officers Club, Edward R. Elko gave a lecture on "Project Vanguard, the IGY Earth Satellite."

Mr. Elko has been active in the field of liquid rocket propulsion since joining the Aerojet-General Corporation in 1948. He is currently in charge of developmental engineering for various missile rocket projects including Bomarc, Aerobee, and the second-stage propulsion engine for Vanguard.

Mr. Elko stated that a minimum of six missiles will be fired during the International Geophysical year. Their expected life will vary from a few days to a few weeks. Velocity and position have to be very accurate, otherwise the missiles will spin in.

The vehicle will consist of three stages of rockets and will carry a sphere, 20 in. in diameter and weighing $21\frac{1}{2}$ lbs., to a height of 300 miles. A minitrack transmitter in the sphere will telemeter a record of radiation properties and meteorite bombardment in outer space.

Although the project is sponsored by the three military services, Mr. Elko pointed out that the basic reason for firing the missiles is scientific curiosity—to gather information on outer space. The missiles will be fired from AFMTC, Cocoa Beach, Fla., starting next year.

ELAINE GETHING, *Secretary*

Texas Section

A Correction: Alexander M. Lippisch, MIAS, who spoke on "Airflow Visualization" at the February 8 meeting of the Texas Section, was introduced as the designer of the Aerodyne. He did not discuss the Aerodyne, however, as this is a classified subject. Dr. Lippisch is Director of the Aeronautical Research Laboratory of Collins Radio Company.

Tullahoma Section

On May 15, the Tullahoma Section met for dinner and a discussion by Col. John R. Roche, Commander of the 513th Troop Carrier Group, Sewart Air Force Base, Tenn. Colonel Roche began by telling his experiences during the Korean conflict while commander of the 437th Troop Carrier Group. He said that during this Korean conflict the Troop Carrier Groups moved over 1 million tons of cargo and over 4 million men, including equipment drops, assault drops, and hospital evacuation.

Models of the Douglas C-133 and Lockheed C-130 with pressurized cabin were on hand for inspection.

The talk was concluded with a movie, *Pipeline in the Sky*, filmed by Fairchild Aircraft Division and now available from the Air Force Library. It pictured troop carrier action in Europe. The movie showed how Fairchild C-119's were being used not only for assault training and emergency supply and evacuation but also to save on Air Force expenditures by shortening shipping time to combat-ready groups from several weeks to 2 days, thus allowing the groups to decrease their spare parts inventory and storage facilities.

Officers elected for the coming year are Jim Delano, Chairman; Lt. Col. Robert Lebeck, Vice-Chairman; Gene Hull, Secretary; and Ray Harvey, Treasurer.

GENE HULL, *Secretary*

STUDENT BRANCHES

The Catholic University of America

Chairman Nicholas Gallipoli introduced Joe Aldi, of Wright Aeronautical Division, Curtiss-Wright Corporation, as the speaker at the April 26 meeting.

Mr. Aldi described the Wright turbocompound 18-cylinder aircraft engine, using slides to illustrate interesting engineering features.

A motion was passed establishing two Max Munk Awards to be given to two members who have distinguished themselves in the service of the Student Branch here.

The following officers were elected for the next school year: Patrick J. Ferriter, Chairman; Charles Spencer, Secretary; Donald R. Geoffrion, Notice Secretary; Pete Bogan, Treasurer; and James R. McGrath, Inter-Engineering Council Representative.

Wings over Turkey, a motion picture describing the growth of the Turkish Air Force in recent years, was shown at the March 22 meeting.

JAMES R. MCGRATH, *Secretary*

Georgia Institute of Technology

Faculty Adviser John J. Harper, MIAS, explained the aims and importance of the Institute to new members at the April 30 meeting.

There was a discussion of the Southeastern Student Conference. Ralph Eden, a student speaker at the conference, urged everyone to begin work on projects and papers suitable for presentation next year.

It was decided to hold the annual IAS picnic May 19 and a dinner meeting May 24.

EUGENE C. KNOX, *Secretary*

Institute of Technology, USAF

One hundred students and faculty members attended the May 16 meeting.

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AC is well on the way to development of control systems that can direct space-rockets on their way.

AC

THE ELECTRONICS DIVISION
OF GENERAL MOTORS
Flint, Michigan
Milwaukee, Wisconsin

Two classified films were shown—an ARDC staff film report and a motion picture dealing with the B-58 bomber.

The following Student Branch officers were elected for the next school year: Capt. Roy E. Hale, Chairman; Capt. G. B. Chamberlin, Vice-Chairman; Lt. A. A. Jancauskas, Secretary-Treasurer; and Capt. Raymond B. Wood, Activities Chairman.

LT. DOUGLAS S. EGAN, JR., USAF
Secretary

Iowa State College

The highlight of the May 16 meeting was a talk by Rial E. Rolfe, of the Loads Department at McDonnell Aircraft Corporation.

Mr. Rolfe, a graduate of Georgia Tech, has been in this work for the past 5 years. His department investigates the structural loads created by gusts, aerial maneuvers, normal and arrested landings, catapult take-offs, etc. To supplement his talk, Mr. Rolfe had some slides and a movie showing loads-testing of jet aircraft operating from a carrier off the East Coast.

MARVIN BAXENDALE, *Secretary*

Kent State University

Norm Bereit, Program Chairman, read his seminar paper on "Principles and Applications of the Ram-Jet Engine" at the May 9 meeting.

Most of the IAS members attended the Industrial Arts Department banquet on May 2. Three members who have since graduated—Jacob Berry, James Menough, and Michael Ramicone—were honored for their high scholastic standing. Thomas E. Baker, of Case Institute of Technology, spoke on "Northeast Ohio: The Perennial Frontier." Dr. Baker also emphasized the need for more high school training in mathematics.

Several members attended the Cleveland Air Show on April 28 and 29.

Bob Fenning is gathering information for an IAS newsletter to be mailed to men who have graduated.

A committee has been appointed to prepare a brochure on the Aviation Technology curriculum.

Bob Shutak has been named Publicity Chairman.

Two new members have been admitted, Clarence Willey and Dan Heister.

At the April 11 meeting, Jacob Berry and Jim Verba read their seminar papers. A. W. Dun spoke at a joint meeting of the IAS Student Branch and the University Flying Club on April 4.

ROBERT FENNING, *Secretary*

Mississippi State College

At the last meeting of the season, May 17, the following officers were elected for the next school year: Chairman, Donald W. Boatwright; Vice-Chairman, Richard N. Stone; Secretary, W. Hugh Parks, Jr.; and Treasurer, L. M. Hawwa.

It was decided at this meeting that the following method of keeping in contact with the graduating members be devised:

Each member, when he starts to work, will send two post cards, containing information such as his address and the company he is working for, back to college. One card will be filed under his name and the other under the name of the company he is working for. Anyone desiring to locate a college friend or to find out who is working at any particular company may write to the branch secretary and receive this information. At the end of each school session, a ditto copy of the location, etc., of each member will be mailed to all members. The supplies and postage necessary for this correspondence will be financed by a payment of $1.00 per member at the time he sends in his cards.

W. HUGH PARKS, JR., *Secretary*

North Carolina State College

The Engineer's Fair was held on April 20 and 21. The two main exhibits presented by the Aeronautical Department

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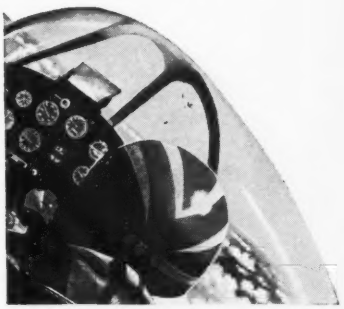
While the "enemy" plane is still far beyond the sight of human eyes, this new radar system detects it. Mounted in the intercepting aircraft, it provides a continuous flow of information about the "enemy position," electronically computed in terms of range and rate of closing. When visual contact has been established, the firing is controlled by the pilot, aided by electronic calculations.

In developing this compact, light-weight, high-performance radar, RCA has achieved a notable simplification of design with a minimum of components. As always, reliability and ease of maintenance have received top consideration. A feature is the bright radar display that permits viewing in broad daylight without a hood. Lock-on may be manual or automatic as the pilot desires.



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Reconnaissance Systems
Infrared Equipment
Military Television
Computers

DEFENSE ELECTRONIC PRODUCTS
RADIO CORPORATION of AMERICA
CAMDEN, N. J.

consisted of the subsonic wind tunnel and a 7-ft. scale model of the Convair B-36 which was built by IAS members. A model P-51 with a pressure distribution setup was in operation in the tunnel throughout the 2 days of the Fair. The IAS exhibits created much interest and no doubt played a large part in winning first place for the department for the third straight year.

The last meeting for this school year was held on May 19. The speakers were the six members who attended the IAS Regional Student Conference held in Atlanta, Ga., on April 26 and 27. Dave Pierce, next year's Chairman, opened the talks and was followed by Keith Verble, Bill Creasy, David Gurley, Jesse Harrell, and Prof. John J. Cleary. Tentative plans were discussed concerning papers and projects for the conference next year.

To conclude the year's activities, the IAS held a picnic at Umstead State Park on Saturday, May 12. About half the members attended, accompanied by wives and friends.

JESSE W. HARRELL, *Secretary*

Northrop Aeronautical Institute

Two students from Northrop Aeronautical Institute won awards in the undergraduate paper competition at the Sixth Annual West Coast Student Branch Conference held May 3 and 4 at the IAS Building in Los Angeles.

First prize went to Charles A. Yost for his paper entitled "Gyroscopic and Variable Center-of-Gravity Forces for a New Design in VTO Aircraft." Mr. Yost described his concept of a two-place helicopter which utilizes gyroscopic forces for stability and control and thus eliminates the usual cyclic-pitch mechanism. This design promises production cost comparable to light planes with performance competitive with conventional helicopters, according to Mr. Yost.

An honorable mention award was created for Theodore A. Heinz for his paper on "The Development of an Experimental Liquid Oxygen-Thiakol Rocket Propulsion System." Mr. Heinz described the design, construction, and static testing of a solid-liquid propellant rocket which he has built but has not fired. This design retains the simplicity of the solid-propellant rocket while offering performance approaching that of complicated biliquid propellant rockets, according to Mr. Heinz.

Other schools represented in the competition were the University of Washington, Oregon State College, Stanford University, and California State Polytechnic College. The remaining award in the undergraduate division, second place, was won by Bud C. Nelson of the University of Washington.

Other activities at the 2-day conference included tours of Garrett Corporation facilities at the Los Angeles International Airport and the Southern California Cooperative Wind Tunnel at Pasadena. On Thursday evening a panel discussion of "The Engineer's Place in the Aviation Industry" followed reports by the chairmen of the Student Branches represented. The awards banquet on Friday night featured a talk by Lt. Gen. Laurence C. Craigie, USAF (Ret.), entitled "The Future Belongs to the Engineer."

GARLAND O. GOODWIN
Vice-Chairman

Oregon State College

Fourteen members of our Student Branch attended the recent regional IAS conference held in Los Angeles May 3 and 4 as one of the group's annual activities. Since we are a considerable distance from Los Angeles and a field trip is required for graduation, the Department of Mechanical Engineering at Oregon State authorized a week for the trip. This gave time to visit various aeronautical facilities en route to the conference.

Arrangements were made for group tours through Ames Aeronautical Laboratory at Moffett Field, Calif., and the flight-test facilities at Edwards AFB. Members of the senior class visited various aircraft companies in the Los Angeles area for employment interviews when the conference was not in session.

At Ames a tour of the High-Speed Research Division was arranged. Ames is the large aerodynamic research center of the NACA on the West Coast. The wind tunnels there work in Mach Numbers ranging from subsonic to well into the supersonic, with one tunnel attaining 3.5 times the speed of sound in an 8 by 7 ft. test section. The full-scale tunnel's test section of 40 by 80 ft. is one of the remarkable facilities available for subsonic work. It has velocities up to 250 m.p.h. and is believed to be the largest of its kind in the world.

On the visit to Edwards AFB, which is located northeast of Los Angeles, some of the latest facilities for actual flight testing of aircraft were seen. The tour was conducted by Capt. B. Beatie, a graduate of Oregon State College. The group heard a talk by an officer in charge of the flight testing in which he gave the step-by-step outline of a complete airplane flight-test program. One of the highlights of this tour was the witnessing of the high-speed rocket sled in operation. In this test, the sled attained a speed of slightly over the speed of sound, propelled by solid-fuel rocket motors.

Some of the installations visited in the Los Angeles area were The Garrett Corporation, Marquardt Laboratories, Southern California Cooperative Wind Tunnel (which is operated by the California Institute of Technology), North American Aviation, Inc., and Lockheed Aircraft Corporation.

At the conference, two Oregon State members presented technical papers. The undergraduate paper was given by Rodney Hugelman on the development of a multichannel remote control system. Leroy L. Presley gave a paper in the graduate division summarizing his thesis work on sharp-edged jet inlets at zero forward velocity. The graduate paper took a second place.

On the last evening of the conference there was a banquet for all participating students and their guests. Awards for the winning papers were presented, and the conference closed with a talk by Lt. Gen. Laurence C. Craigie, USAF (Ret.), now the Vice-President of Hydro-Aire, Inc., but formerly Air Force Deputy Chief of Staff for Development. Speaking on "The Future Belongs to the Engineer," he summarized what the engineer means to the high technical level of our modern and future society.

The annual elections took place May 15. The new officers are Chairman, Robert L. Balch; Vice-Chairman, Gustavus M. Supe; Secretary, William K. Howell; Treasurer, Jack D. Dennon. Professor H. D. Christenson was elected Faculty Adviser of the Student Branch.

WILLIAM K. HOWELL, *Secretary*

Parks College of Aeronautical Technology

The annual picnic, scheduled for the first week in July, was planned at the June 7 meeting. Galen Johnston presided.

James M. Llewellyn, a student member, gave a talk on rockets. Rockets were first used in the year 1232, he said, by the Chinese. Artillery was not invented until a few centuries later. A man named Paulet was said to have made the first liquid-propellant rocket about 1900.

Jim discussed three features of the rocket—the propellant (liquid or solid), the injectors, and the methods of cooling.

GERALD J. PANEK, *Secretary*

The Pennsylvania State University

William Kleinbauer was elected Chairman for the coming school year and Robert Walacavage, Secretary-Treasurer, at the meeting on May 16. The Vice-Chairman will be chosen in September.

JOEL PETERSON, *Secretary*

Polytechnic Institute of Brooklyn

Ross Fleisig, of the Sperry Gyroscope Company, spoke on "Automatic Flight

Capital Airlines' new fleet of Vickers Viscounts cruise at 335 mph. So quietly and smoothly, you can balance a quarter on edge. They are powered by the new Rolls-Royce "Dart" turboprop engine. Nickel...in alloyed materials... accounts for 6% of this engine's total weight.

Rolls-Royce turboprops depend on nickel-containing alloys

THE ROLLS-ROYCE "DART," a turboprop engine now powering Viscount airliners, has provided the airline passenger with new standards for smooth, quiet air travel. Most notable is the reduction of noise and vibration.

Internal heat was a major problem to the Rolls-Royce engineers who designed this engine. As in jet engines, operating conditions in the Dart require high strength in vital parts despite intense heat... as well as exceptional resistance to high-temperature corrosion and oxidation.

Accordingly, the designers turned to nickel-alloyed materials for the desired properties in turbine blades, combustion liners and other key parts. Alloys used in the Dart are tabulated here because they may offer advantages to you. Whatever your metal difficulties, let us help you with our wide practical experience. Send details of your problem, for our suggestions.

Part	Material
Compressor Assembly	
Impeller Shaft	2% Ni-Cr-Mo case-hardened steel
Rotating Guide Vanes	4% Ni austenitic steel
Combustion System	
Nozzle Guide Vanes	12% Ni–23% Cr–3% W austenitic steel
Combustion Chamber	Cast 60% Ni-Cr alloy
Flame Tubes, and Nozzle Box (Gas temperatures to 1560°F.)	"Nimonic* 75," 76% Ni–20% Cr alloy
Fuel Burners	Type 310 (25% Ni–20% Cr) stainless steel
Turbine Assembly	
1st Stage Rotor Disc	13% Ni–13% Cr–10% Co austenitic alloy
1st Stage, 131 Rotor Blades	"Nimonic* 80A," 76% Ni–20% Cr alloy
2nd Stage, 103 Rotor Blades	"Nimonic* 80A," 76% Ni–20% Cr alloy
All Stator Blades	12% Ni–23% Cr–3% W austenitic alloy
Exhaust Unit	
Exhaust Casing	18% Cr–8% Ni+Ti, Type 321 stainless
Tail Cone	"Nimonic* 75," 76% Ni–20% Cr.
Reduction Gears	2% Ni alloy heat-treated steel
Rotor Shaft	19% Cr–14% Ni austenitic steel

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Control and the Aeronautical Engineer" at the May 1 meeting.

He defined automatic flight control as "those means for directing and stabilizing the flying vehicle without pilot control." Two major functions of an automatic flight control system, he said, are the *direction function*, which is to get the vehicle from one point to the other on the earth, and the *stabilization function*, which is to control the vehicle in pitch, yaw, and roll. The flight control system must control heading, altitude, forward speed, climb, and cruise as specified by the vehicle manufacturer.

An example of a flight control system is a speed-altitude control system. The static pressure from the pitot tube is fed into a pressure pickoff, which sends an electronic signal to an altitude computer, which then compares the actual altitude to a command altitude that has been set into the computer by the pilot or programed into a missile. The computer sends a signal to the servoamplifier, which in turn sends the amplified signal to the elevator servomechanism, which changes the vehicle's pitch. The pressure signal is fed into this end of the system also to complete the closed loop.

The speed control system uses the total pressure and feeds it into an airspeed computer, along with the static pressure signal from the altitude control. This is compared with the command speed, and a signal sent to the servoamplifier which controls the throttle servo, which affects the vehicle's speed. The pressure is fed back into the system at this point to again close the loop.

In a missile, the flight control system assumes the entire burden of control since there are no human monitors. The designers of the system must know the trajectory the missile is to fly. This depends upon the requirements of the missile performance. This, in turn, depends upon the tactical considerations involved.

In the design of such systems, the aeronautical engineer defines the airframe characteristics and studies the overall requirements of the closed loop.

▶ "Flight Testing" was the subject of a talk at the April 10 meeting by Lynn E. Radcliffe, of Grumman Aircraft Engineering Corporation. He outlined the main objectives of the Flight Test Department and traced the historical development of flight testing from the beginnings of powered flight to the present day.

The work done by the Flight Test Department today is divided into two different periods. The first period covers the time from the beginning of an airplane's design to the time when production models are first delivered. During this period, members of the Flight Test Department must educate themselves as to the new features of the airplane, schedule tests in coordination with the various engineering departments, determine instrumentation requirements, set up data-reduction and analysis methods, coordinate the flight testing with the shops to provide shop support for the program, conduct the tests, and issue reports on the results of the tests.

The second period follows the aircraft through its production program and the various improvements made on the production aircraft. Some of the problems concerning the Flight Test Department are evaluation of major aerodynamic and power-plant modification, development programs to improve mechanical systems and flight performance, and evaluation of new external stores and electronic equipment.

Soon after the first flight of the Wright brothers' airplane, flight testing began. The first aircraft needed only the basic questions answered: Would it fly? Could it be made to turn? etc. Quantitative results were of minor importance. Even after World War I, when aircraft performance had become of great interest, the only instruments available were an air-speed indicator, an altimeter, and an engine r.p.m. indicator. It was not until the 1930's that some of the larger companies began to place reliance upon instruments for flight testing. Engine temperature and manifold pressure measurements were introduced. In large aircraft, flight engineers recorded test data in flight.

By the 1940's, the need for both better recording instruments and professional test pilots with formal engineering education became apparent. The war prevented too many technique improvements, since the accent was on getting the airplanes into service. After the war, many new developments, including telemetering and the use of electronic accelerometers, allowed much more accurate information to be recorded. This was necessary because the manufacturers soon found that their airplanes were outstripping theoretical knowledge. This forced flight testing to assume a more fundamental nature.

▶ A chapter of the national honorary aeronautical fraternity, Sigma Gamma Tau, has been formed at Polytechnic Institute of Brooklyn. Elected as its first President was Frank H. Schlee, Vice-Chairman of the IAS Student Branch.

HOWARD BAUM
Recording Secretary

Purdue University

Forty-one members attended the last meeting of the season on May 22.

The following officers were elected for the fall term: Chairman, Dave Clingman; Vice-Chairman, George Koland; Secretary, William Leach; Treasurer, William Swoger; and Faculty Adviser, P. E. Stanley.

The meeting closed with the showing of an historical movie on aviation, *We Saw It Happen.*

WILLIAM B. LEACH, *Secretary*

Rensselaer Polytechnic Institute

The Annual Scholastic Award was presented to Robert M. Bowman, '56, at the final meeting of the year on May 15.

The speaker of the evening was L. Sullivan, Assistant Head of Preliminary Design, Grumman Aircraft Corporation. His subject was "Design of Aircraft."

Mr. Sullivan stated that the two basic problems of preliminary design are to decide what can possibly be included in a design from a given state of the art and to determine if a reasonable airplane can be obtained from military specifications. He then explained how the gross-weight factor is most important in deciding whether a design is reasonable. Cost, compatibility with existing facilities, and man-hours required to produce an aircraft can be estimated from the gross-weight factor. The gross weight at take-off can be split into structural, fuel, power-plant, and "job" weights. Mr. Sullivan explained the constituents of each of these elements. For example, the "job" weight consists of pay load, equipment, and the crew and their provisions. The importance of charts of past results in estimating these elements was discussed. Mr. Sullivan also considered developments which influence the weight elements, such as the use of a nuclear engine, which would radically decrease the weight of fuel but increase the engine weight per pound of thrust.

ROBERT E. KELLY
Secretary-Treasurer

San Diego State College

Officers for the fall term were elected at the May 22 meeting. Norman Huff was elected Chairman; Chase Allen, Vice-Chairman; Michael D. Chilcote, Secretary; and Irving Gere, Treasurer.

A film on the Nike guided missile was shown. Several members described their experiences at the West Coast Student Conference in Los Angeles.

Several members volunteered to assist in cataloging technical magazines in the IAS library in the San Diego headquarters of the Institute during the summer.

The Sky Is No Limit, a film showing the firing of an experimental rocket at Holloman AFB, was presented at the May 8 meeting.

MICHAEL D. CHILCOTE, *Secretary*

Are **you** the engineer who can move in fast company?

If you're the sort of engineer who's happiest when he's setting the pace, you might do well to scan the list of jobs now open at Lear—a company that's blazed the way in filling the precision needs of aviation. You will receive a prompt reply by writing to Don Cook, Dept. E-2, 3171 South Bundy Drive, Santa Monica, Calif. Excellent openings available in Grand Rapids, Michigan; Cleveland, Ohio; Arizona; Santa Monica, California.

Aerodynamics
Aeronautical design
Aircraft electrical systems
Automatic flight controls
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Communications (aircraft)
Electro-mechanics
Electronic packaging
Flight reference systems
Flight instrumentation
Fractional H. P. motors
Gyroscopes
Hydraulic systems
Magnetic amplifiers
Missile controls
Navigation systems (aircraft)
Process engineering
Pumps (aircraft and industrial)
Quality control
Radar
Servo mechanisms
Systems analysis
Test equipment design
Transistorized circuitry

LEAR

Tri-State College

The spring banquet was held on May 21, with A. H. Cronkhite, Chief of Production Engineering, Aero Design and Engineering Company, as the guest speaker. He described various types of commercial aircraft, pointing out the advantages of executive aircraft for use by businessmen. He invited the students to go up for a demonstration ride in the Aero Commander, saying he would make a plane available at the local airport the following day. A company movie entitled *Oklahoma City* was shown.

New officers for the fall term were introduced at the banquet: Roland "Speed" Harman, Chairman; Don Dupre, Vice-Chairman; Dick Callaway, Secretary; and Don Boyer, Treasurer.

A motion picture, *PBM-3 Wing Destruction Test*, was presented at the May 17 meeting. James Chapman presided.

R. JULES DUSSIA
Vice-Chairman

University of Alabama

William Caudle presided at the May 8 meeting. Discussion was centered on the IAS picnic to be held at Moundville May 12. It was decided to elect officers for next fall at the picnic.

J. O. NICHOLS, *Secretary*

University of Florida

Harold Luskin, FIAS, of Douglas Aircraft Company, Inc., was the speaker at the April 24 meeting. He is Assistant Chief—Aerodynamics, of the Santa Monica Division.

Mr. Luskin was introduced by Faculty Adviser John W. Hoover, MIAS, who said that, after working on many military planes, Mr. Luskin was now more concerned with guided missiles and hypersonic flight.

The problems that Mr. Luskin discussed were the combination of range with high-speed flight and the prevention of damage inflicted on jet engines by loose debris.

In his discussion of combining range with high-speed flight, Mr. Luskin compared subsonic, supersonic, and hypersonic flight characteristics in respect to fuel heat values, engine efficiency, and lift-drag ratios. Using graphs and illustrations, Mr. Luskin showed that the range of airplanes drops enormously in the supersonic regime, making the airplane impractical at hypersonic speeds. On the other hand, the range of rockets in the hypersonic region *increases* with the square of the velocity according to the formula, $R = V^2/2g$, where R is range, V is velocity, and g is the acceleration of gravity. Commercially speaking, Mr. Luskin showed that only subsonic transports will be economically sound. However, he voiced the opinion that the future might bring some revolutionary advances that will push air transport into the supersonic and hypersonic ranges.

The second topic that Mr. Luskin discussed was the problem of preventing debris from being sucked into a jet engine while it is in operation, either on the ground or in the air. The debris is carried to the engine by the forces of strange types of vortices created by the suction of the engine. These forces have never been calculated, and engineers have not been able to solve the problem of neutralizing them. Mr. Luskin showed a series of slides illustrating both the vortices and the intensive research that is now being conducted on the problem. The slides pointed out the fact that the vortices form not only between the engine and the ground but also between two engines that are placed close together in the air. Mr. Luskin stated that the problem of the vortices is becoming more acute because the latest designs are placing jet engines close to the ground.

In conclusion, Mr. Luskin mentioned that aviation is presenting a new series of problems to the engineer. He stated that, contrary to some beliefs, the field of aviation is just beginning to open new frontiers.

The meeting closed with a color film entitled *X Minus Zero*. Released by The Glenn L. Martin Company, it showed the launching and advance preparations of a TM-61 Matador guided missile at Patrick AFB, Cocoa, Fla.

JOHN DAVID ANDERSON
Recording Secretary

University of Kentucky

For the May meeting, the seniors invited all members of the Student Branch and their guests to a garden party at Dr. Karl O. Lange's farm near Lexington.

Since it was the last affair of the year, it was decided to have a picnic instead of a technical meeting for the purpose of attracting new members and to provide an opportunity for the graduating and nongraduating members to get together for the last time.

WALTER J. BLACKSON, *Secretary*

University of Maryland

Robert Beale, Lead Rocket Propulsion Engineer on the Vanguard Project for The Glenn L. Martin Company, spoke about the earth satellite at the May 15 meeting. Since much of the project is classified, he discussed the Viking rocket vehicle as an example of a similar type of rocket. The speaker was introduced by Arthur Guess, a for-

mer professor at the University of Maryland who is now employed by The Glenn L. Martin Company.

Mr. Beale began his talk by describing the physical specifications of all three stages of the Vanguard Project and the Viking rocket. He then discussed the flight path of the Vanguard vehicle and its guidance system. He said the satellite would have an elliptical orbit and a period of about 90 min. Mr. Beale then discussed the performance, guidance, and purpose of the Viking rocket.

After the talk a motion picture, *Horizon Unlimited*, was presented. This film, produced by Martin, depicted the history of the Viking rocket.

Next year's officers were elected at this meeting: Chairman, Tom Finch; Vice-Chairman, Paul Fisher; Secretary, Gail Wisser; and Treasurer, Braxton Dunn.

H. E. HUNTER, *Secretary*

University of Michigan

Stan Smith, who represented this Student Branch at the Detroit Section's Student Conference at University of Detroit, read his paper on "An Atomic-Powered Ram-Jet" at the May 8 meeting.

Students who went to Detroit for the conference were guests of the Michigan faculty at the banquet.

Four new members joined the Student Branch at this meeting. Don Lascody led a discussion of flying clubs. May 19 was set as the date for the annual IAS-Faculty picnic.

FRED STEGENGA, *Secretary*

The University of Oklahoma

Hope Biggers and John Jones, of the Civil Aeronautics Authority, spoke on "Some Considerations in Aircraft Design" at the May 8 meeting. They described present and probable future trends and conducted a discussion period. Forty members and guests were present.

Jerry Mrazek was announced as winner of the annual Lecture Award, and Warren Adam received the Scholarship Award.

Officers elected for next year were Jim Biggers, Chairman; Joe Noyes, Vice-Chairman; and Dick Brace, Secretary-Treasurer.

THOMAS B. SHOEBOTHAM
Secretary-Treasurer

University of Pittsburgh

Richard Huppertz, Secretary of the Pittsburgh Soaring Association, spoke on "Flight Without Power" at the May 3 meeting. He covered the history and development of the sailplane and explained how it obtains lift from the air currents.

These new officers have been elected: Donald Rooney, Chairman; Raymond Dishong, Vice-Chairman; Dennis Neuman, Corresponding Secretary; and Marian Sample, Recording Secretary and Treasurer.

JOHN M. VASILAUSKAS, *Secretary*

University of Wichita

Alan Pope, Supervisor of the Experimental Aerodynamics Division of Sandia Corporation, spoke on "Some Experiences with Atomic Weapons" at the May 14 meeting.

He said that his company, which is concerned with the production of atomic weapons, is interested in hiring any engineer who can obtain the proper security clearance.

Besides weapon shape and bomb-bay design, the work done by an aerodynamicist at Sandia includes study of the reflection and refraction of the shock wave created by an atom bomb. This shock wave can vary as much as 3,000 to 1, depending on whether it is concentrated or dispersed by atmospheric conditions.

After his talk, which was intended to "bring us out of the closet" concerning atomic weapons, Mr. Pope showed a film, *Operation Sandstone*, which dealt with the preparations preceding the sixth, seventh, and eighth atom bomb tests on Eniwetok.

The Scholastic Award of the IAS Student Branch was presented to Walt Keeler. Forty-five members and guests attended the meeting.

WARREN CHICHESTER, *Secretary*

West Virginia University

Papers on "Automatic Pressure-Measuring Devices in High-Speed Wind Tunnels" and "Missiles" were presented by Dick Hamilton and Don Brown, respectively, at the May 16 meeting. Donald Peters presided.

The following officers were elected for next year: Steve Lewellen, Chairman; Fred Sachs, Vice-Chairman; William Smith, Secretary-Treasurer; Calvin Wilson, Corresponding Secretary; and Leon Z. Seltzer, AFIAS, Head of the Aeronautical Engineering Department, Honorary Chairman.

At the May 2 meeting, Ray Herring presented a paper on "Problems of Space Travel" and Richard Walters read his paper on "The Flow of Air over Airfoils at Low Reynolds Numbers."

KENNETH CONN
Corresponding Secretary

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Dane, Paul H., Ae.E., Col., USAF; Prof., Thermodynamics, USAF Academy, Lowry AFB.

Famme, Joseph H., Asst. Chief Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Latimer-Needham, C. H., M.Sc., Engrg., Chief Executive, Aero. & Engrg. Divs., R.F.D. Co., Ltd. (England).

Lipp, James E., Ph.D., Tech. Asst. to Dir.—Devel. Planning, Lockheed Aircraft Corp. (Burbank).

Walsh, James E., B.S., Sr. Group Engr. "A," Supvr., Struct. Dynamics Unit, Boeing Airplane Co. (Seattle).

Wazelt, Friedrich G., Dipl. Ing., Proj. Engr., Lycoming Div., AVCO Manufacturing Corp.

Zimmerman, Don Z., M.S. in Ae.E. (Meteorology), Brigadier Gen., USAF, Deputy Dir.—Devel. Planning, Hq. USAF.

Transferred to Associate Fellow Grade

Bloom, Martin H., Ph.D., Assoc. Prof., Dept. of Aero. Engrg. & Applied Mech., Polytechnic Institute of Brooklyn.

Brull, Maurice A., Ph.D. in Ae.E., Head, Analytical Method Group, Struct. Sect., Bell Aircraft Corp.

Fuhrman, Robert A., M.S. in Engrg., Chief, Tech. Sect., Ryan Aeronautical Co.

Ivanovic, Nicholas P., B.S.M.E. (Aero.), Tech. Dir., Naval Ship Installation Test Facility.

Lundin, Bruce T., B.S., Chief, Engine Research Div., Lewis Flight Propulsion Lab., NACA.

Meyer, Corwin H., Sr. Engr. Test Pilot, Grumman Aircraft Engineering Corp.

Tydon, Walter, Chief Engr. & Dept. Head, Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.

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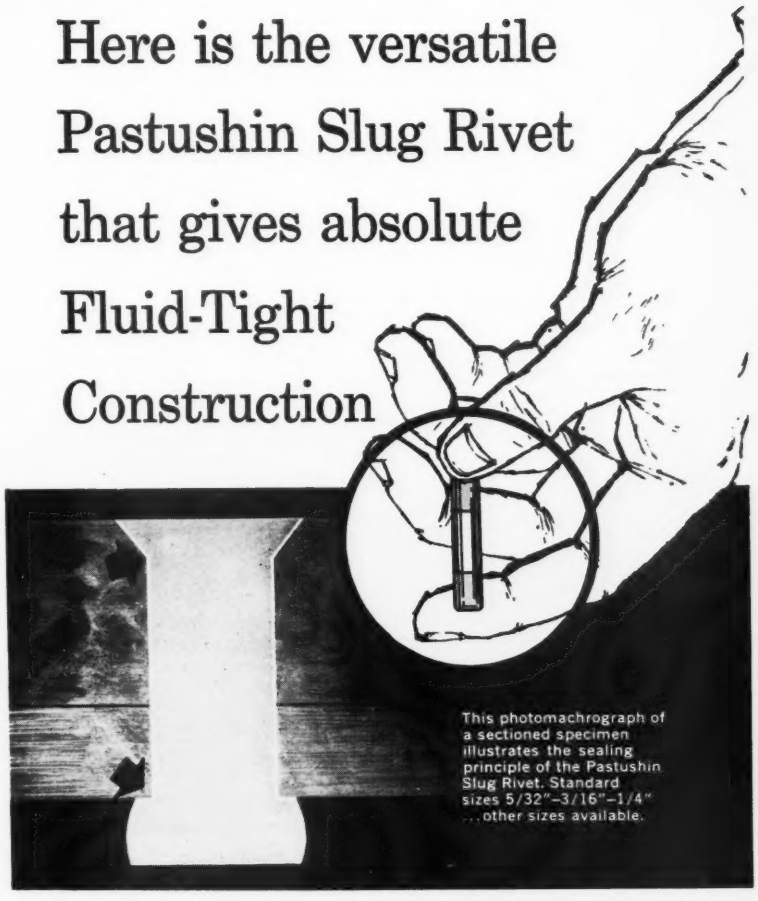

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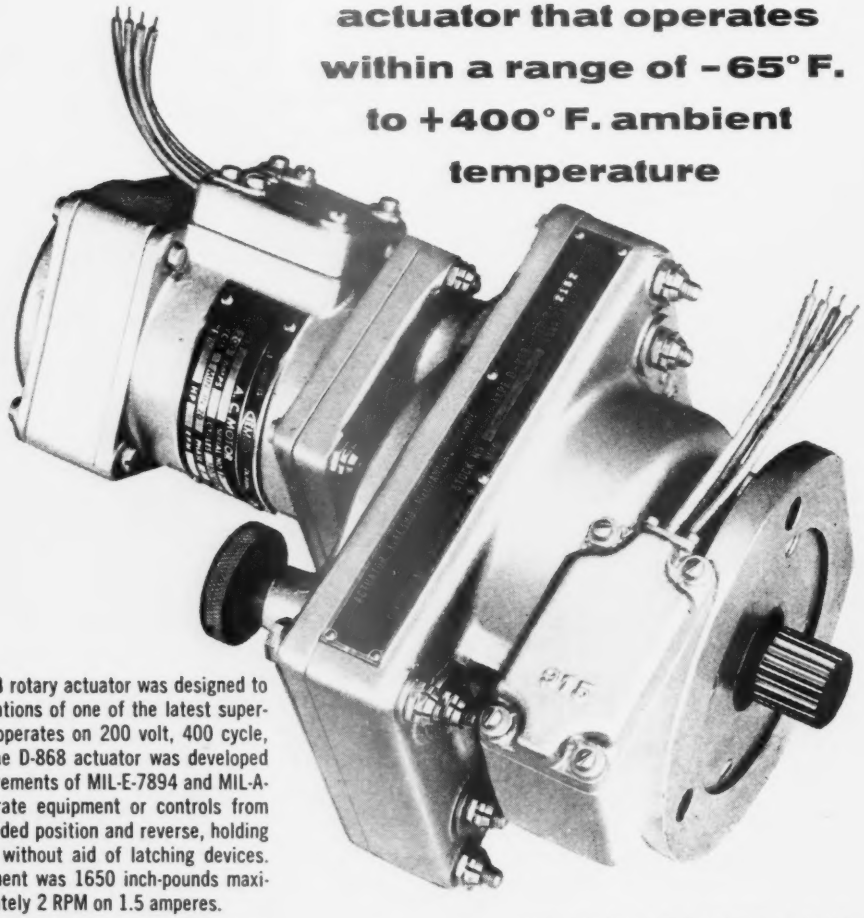

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Acoustics, Sound, & Noise

A Flight Test Investigation of the Sonic Boom. Marshall E. Mullens. *USAF FTC TN-56-20*, May, 1956. 35 pp. Results of tests to obtain time histories of the variation in static pressure caused by the shock waves of an F-100 aircraft instrumented for static pressure measurements through the shock waves generated by a second F-100.

A Re-Determination of the Equal-Loudness Relations for Pure Tones. D. W. Robinson and R. S. Dadson. *Brit. J. Appl. Phys.*, May, 1956, pp. 166–176. 14 refs. Experimental investigation to develop methods for computing the loudness levels of complex sounds from their spectrum analyses.

Damage Due to Aircraft Noise. Jean T. Lacour. *Interavia*, No. 4, 1956, p. 258. Discussion of legal aspects of aircraft noise arbitrarily divided into two categories: noise produced by aircraft in flight outside the immediate neighborhood of airports and noise in the neighborhood of airports caused by the aircraft take-off and landing operations.

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Aerodynamic Calculation of a Fan. (*J. M. Voith Co., Heidenheim, VL Rep. 13109*, Apr. 21, 1947). *Sverdrup & Parcel Transl. Rep. X-5*, Feb., 1956. 73 pp. Analysis of the fan operation to determine the diameter-to-hub ratio, coefficient of lift, blade efficiency, and blade coordinates. Includes strength calculations, taking into account centrifugal and air forces, mass forces at starting, and twisting loads, and a calculation of natural frequency and strength of the hubs.

Równanie Boltzmanna i Jego Znaczenie w Teorii Gazów. Zdzisław Szymański. *Rozprawy Inżynierskie* (Warsaw), No. 4, 1955, pp. 501–553. 39 refs. In Polish, with summaries in English and Russian. Analysis of gas phenomena using phenomenological hydrodynamics, kinetic theory, and statistical mechanics. Fundamental assumptions of the kinetic theory of gases are represented by the kinetic distribution function. Boltzmann equation is solved by the Maxwell velocity distribution law, and the Enskog-Chapman-Burnett theory is used to determine kinetic coefficients.

Über die Bewegung starrer Körper mit nichtholonomen Bindungen in einer inkompressiblen Flüssigkeit. T. P. Angelitch. *ZAMM*, Sept.-Oct., 1955, pp. 345–347. In German. Study of the motion of a rigid body with nonholonomous connections in an incompressible fluid.

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A Note on Transient Aerodynamic Heating. Eugene Covert and Frank Durgin. *J. Aero. Sci.*, July, 1956, pp. 699, 700. Development of a general method of determining heat transfer through a laminar boundary layer with arbitrary surface-temperature distributions. Application is made to the problem of calculating the temperature response of a hemisphere which has been subjected to step function in velocity.

Measurement of Recovery Factors and Heat Transfer Coefficients with Transpiration Cooling in a Turbulent Boundary Layer at $M=3$ Using Air and Helium as Coolants. Appendix A—**Extension of Film Theory to Diffusion Cases Where the Fractional Concentration of Foreign Gas at the Wall Differs from Unity.** B. M. Leadon and C. J. Scott. *U. Minn., Inst. Tech. Dept. Aero. Eng. Res. Rep. 126*, Feb., 1956. 32 pp.

The Influence of Free-Stream Turbulence on Heat Transfer by Convection from an Isolated Region of a Plane Surface in Parallel Air Flow. Alan Edwards and B. N. Furber. *Chartered Mech. Engr.*, May, 1956, pp. 255, 256. Abridged.

Empirical Relationships for Local Coefficients of Skin Friction in Subsonic Air Streams. J. N. Hool. *Australia ARL AN 145*, June, 1955. 24 pp. 13 refs. Comparison of skin-friction equations with experimental results obtained for turbulent, two-dimensional subsonic flow under a rising pressure gradient.

Measurement of Skin Friction Using Surface Tubes. J. N. Hool. *Australia, ARL AN 144*, June, 1955. 16 pp. Extension of the Stanton surface tube technique to measurements of skin-friction intensity. A simple surface tube is described, and a method of varying the surface tube calibration curves to cover other fluids and temperature is developed. Includes an empirical equation for the determination of skin-friction intensity values from surface tube - static tapping readings and the width of the surface tube opening.

Thermal Conditions Associated with Aircraft in Flight. Martin Bloom. *USAF WADC TR 55-169*, Mar., 1956. 66 pp. 94 refs. Review of developments in the field of forced-convection heat transfer to provide structural specialists with aerodynamic boundary-condition data required to solve temperature-distribution problems.

The Temperature of Materials at High Flight Speeds and the Problems Involved. A. S. Hartshorn. *Gt. Brit., RAE TN Aero. 2397*, Sept., 1955. 30 pp. 15 refs.

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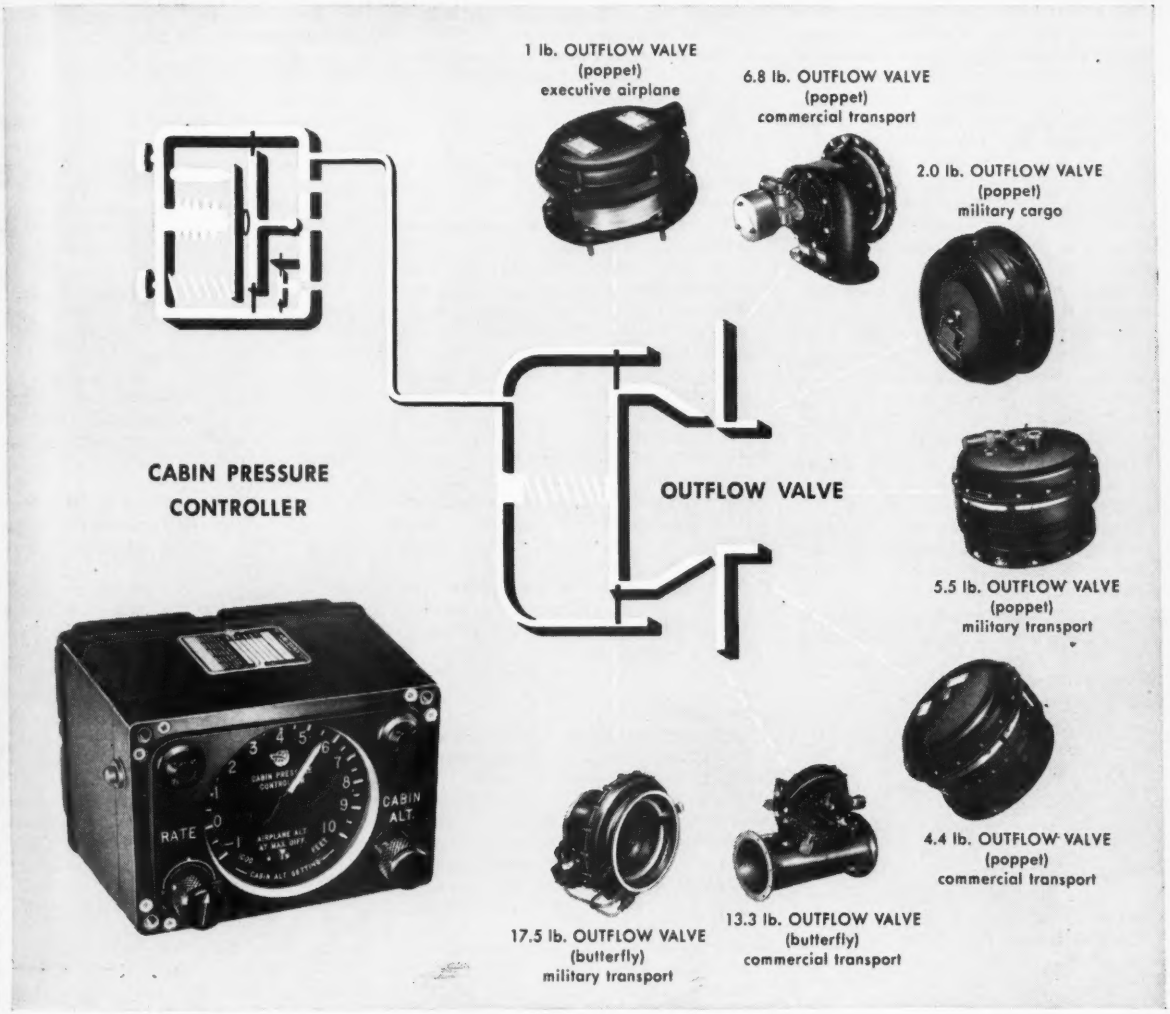

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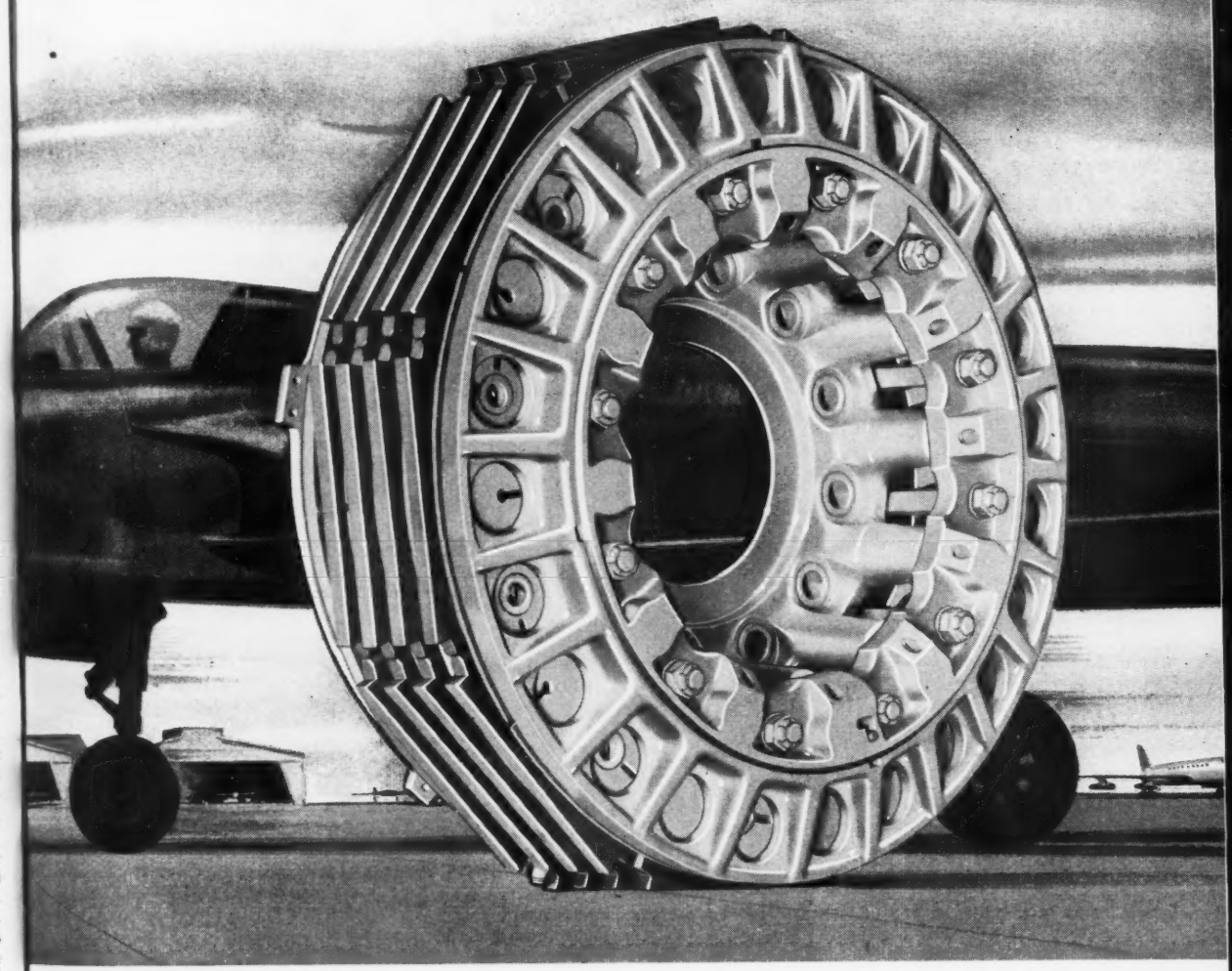

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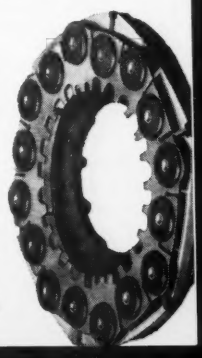

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Stability & Control

Applications of Matrix Operators to the Kinematics of Airplane Motion. Malcolm J. Abzug. *J. Aero. Sci.*, July, 1956, pp. 679–684. Development of kinematic relationships includes (1) the direct and inverse relationships between angular velocities and orientation angle rates, (2) the projections on earth axes of the small-disturbance motions calculated by classical airplane dynamic stability theory, (3) azimuth and elevation angles of a target on tracking airplane axes, (4) relationships between the orientation angles of NACA stability axes and arbitrarily aligned airplane body axes, and (5) the indications of free gyros (gimbal angles).

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Low-Speed Wind-Tunnel Tests on a Model of a Jet Tailless Aircraft. J. Trouncer and G. F. Moss. *Gt. Brit., ARC R&M 2843* (Jan., 1947), 1956. 36 pp. BIS, New York. $1.71. Results of longitudinal and lateral stability tests given as coefficients of lift, drag, and pitching.

Contribuţii la Studiul Stabilităţii Longitudinale a Avionului în Evoluţiile cele mai Defavorabile. Tiberiu Hacker. *Stud. Cerc. Mec. Aplic.*, July–Dec., 1955, pp. 269–297. 10 refs. In Rumanian. Study of the longitudinal stability of an aircraft under unfavorable conditions. Equations of motion are derived for trajectories of rectilinear motion, and the perturbation amplitude of the angle of incidence and of the angular velocity of pitch is determined.

Wings & Airfoils

Determination of Velocity and Pressure Distribution Along the Surface of Annular Aerofoils with Thick Symmetrical Sections. Svetopolk Pivko. *J. RAeS*, May 1956, pp. 348–350.

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Notes on the Transonic Movement of Wing Aerodynamic Centre. S. B. Gates. *Gt. Brit., ARC R&M 2785* (May, 1949), 1956. 34 pp. 31 refs. BIS, New York, $2.00. Analysis of the backward movement of the aerodynamic center of wing shapes as the flow progresses from incompressible, through subsonic, to supersonic, with disregard of the shock-wave regime. Development of a new geometrical parameter enables the division of wing shapes into six classes: delta, two lozenges, reversed delta, arrowhead, and reversed arrowhead.

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Theoretische und experimentelle Untersuchungen an schiebenden Flügeln, insbesondere an Pfeil- und Deltaflügeln. K. H. Gronau. *Braunschweig, Deutsche Forschungsanstalt Luftfahrt, Inst. Aerodynamik, Bericht 55/9*, Dec. 20, 1955. 122 pp. 25 refs. In German. Development of a practical method for the calculation of lift distribution on swept wings of a given shape in incompressible flow.

Aerofoil Design in Two-Dimensional Subsonic Compressible Flow. L. C. Woods. *Gt. Brit., ARC R&M 2845* (Mar., 1952), 1955. 54 pp. BIS, New York. $2.52. Derivation of design equations by extending the Lighthill method to the case of subsonic compressible flow. The Lighthill equations are shown to be a special case of general equations for airfoil design. Velocity distribution is defined numerically, and the nose radius is controlled by closure conditions for the airfoil.

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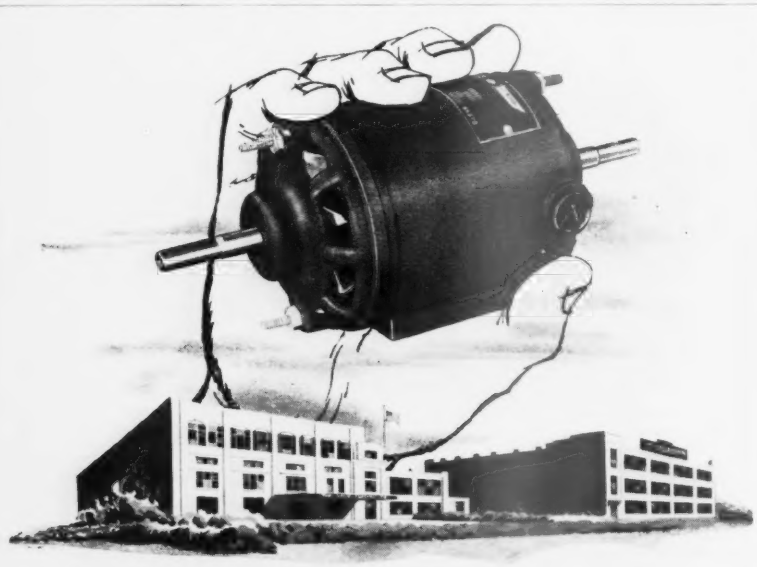

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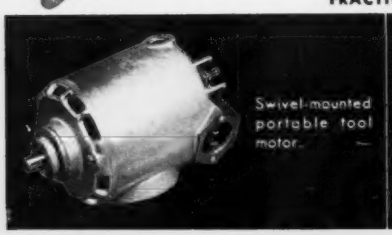

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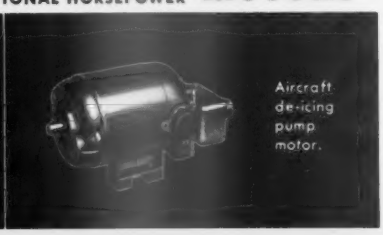

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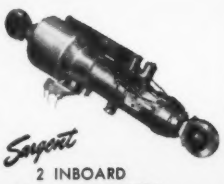

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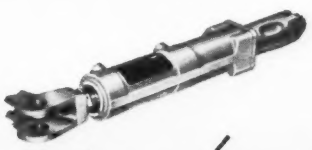

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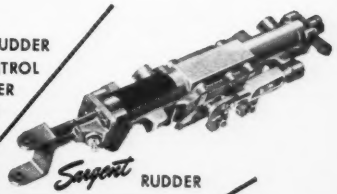

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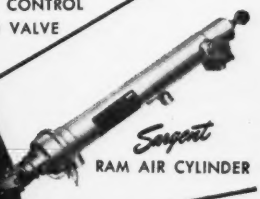

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Untersuchungen über den Abwind hinter Deltaflügeln bei inkompressibler Strömung. K. Gersten. *Braunschweig, Deutsche Forschungsanstalt Luftfahrt, Inst. Aerodynamik, Bericht 55/22,* Jan., 1956. 32 pp. 14 refs. In German. Theoretical and experimental investigation of the downwash behind delta wings in incompressible flow, measured by a tuft grid method. Numerical values for the induced velocity are given from photographic recordings of the grids. Theoretical determination of the downwash is obtained from the calculation of the lift distribution, using the Truckenbrodt airfoil theory.

Minimum Wave Drag for Arbitrary Arrangements of Wings and Bodies. Robert T. Jones. *U.S., NACA TN 3530,* Feb., 1956. 11 pp. 10 refs. Study of the problem of determining the minimum possible value of the wave resistance obtainable by any disposition of the aircraft elements within a definitely prescribed region. Conditions which must be satisfied in the case of minimum drag are derived under the assumption that the total lift and the total volume of the aircraft are given.

On the Use of Interfering Flow Fields for the Reduction of Drag at Supersonic Speeds. Antonio Ferri and Joseph H. Clarke. *Polytech. Inst. Bklyn. Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 304,* Mar., 1956. 71 pp. 17 refs. OSR-supported study including a general outline of possibilities for favorable wave interference between supersonic aircraft components. The interference between a three-dimensional wing with swept leading edges and a small reflecting surface in biplane arrangement is discussed in terms of the linearized flow theory. Relationships are developed to facilitate the determination of the interference drag of a large class of three-dimensional configurations neglecting the calculations of the flow field.

Generalized Indicial Forces on Deforming Rectangular Wings in Supersonic Flight. Harvard Lomax, Franklyn B. Fuller, and Loma Sluder. *U.S., NACA Rep. 1230,* 1955. 27 pp. Supt. of Doc., Wash. $0.30. Development of a method to determine the time-dependent flow over a rectangular wing undergoing small vertical distortion expressed as polynomials involving spanwise and chordwise distances. The solution for the velocity potential is presented in a form analogous to that of Evvard for steady supersonic flow having the reflected area.

Comparison Between Experimental and Predicted Downwash at a Mach Number of 0.25 Behind a Wing-Body Combination Having a Triangular Wing of Aspect Ratio 2.0. Norman E. Sorensen and Edward J. Hopkins. *U.S., NACA TN 3720,* May, 1956. 29 pp.

Investigation at High Subsonic Speeds of a Body-Contouring Method for Alleviating the Adverse Interference at the Root of a Sweptback Wing. Appendix—**Method of Body Modification.** John B. McDevitt and William M. Haire. *U.S., NACA TN 3672,* Apr., 1956. 38 pp. 14 refs. Test results on several bodies used in combination with a 35° sweptback wing, modified according to Küchemann by counteracting the distorting velocities at the wing-body junction. At subcritical speeds the results are insignificant, but above the critical Mach Number aerodynamic characteristics are improved.

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Elastic Waves in Anisotropic Media. J. L. Synge. *U.S., NBS Rep. 4601,* Apr. 2, 1956. 24 pp. USAF-supported study.

Free Oscillations of Systems Having Quadratic Damping and Arbitrary Restoring Forces. Karl Klotter. (*ASME West Coast Conf., Monterey, Sept. 12, 13, 1955.*) *J. Appl. Mech.,* Dec., 1955, pp. 493–499. Solution of second-order differential equations of motion with one degree of freedom for determining the exact relationships between any two consecutive maximum displacements.

Asupra Determinării Vibrațiilor Proprii ale Construcțiilor. M. Mișicu. *Stud. Cerc. Mec. Aplic.,* July–Dec., 1955, pp. 447–455. 11 refs. In Rumanian. Development of a method for the calculation of natural frequencies of systems with several degrees of freedom.

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Hinge-Moment Derivatives for an Oscillating Control. C. S. Sinnott. *Gt. Brit., ARC R&M 2923* (Sept., 1953), 1955. 11 pp. BIS, New York. $2.15. Derivation of hinge-moment coefficients for an airfoil-control combination in a low-speed wind tunnel by means of the thin "equivalent profile" method which takes into account the effects of thickness and viscosity.

Stationary Principles for Forced Vibrations in Elasticity and Electromagnetism. J. L. Synge. *U.S., NBS Rep. 4582,* Mar. 26, 1956. 19 pp. OSR-sponsored theoretical analysis leading to a simple geometric presentation based on the Prager-Synge concept of function-space.

On the Vibration of Elastic Bodies Having Time-Dependent Boundary Conditions. J. G. Berry and P. M. Naghdi. *Quart. Appl. Math.,* Apr., 1956, pp. 43–50.

An Aeroelastic Parameter for Estimation of the Effects of Flexibility on the Lateral Stability and Control of Aircraft. William P. Rodden. *J. Aero. Sci.,* July, 1956, pp. 660–662. Derivation of an aeroelastic parameter introduced in a quasi-steady analysis which separates the effects of Mach Number from those of altitude on the lateral motion of a flexible wing.

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Teoria e Applicazione dei Modelli Strutturali Nelle Costruzioni Aeronautiche. Giuseppe Gabrielli. *ZFW,* May–June, 1956, pp. 198–202. 22 refs. In Italian. Evaluation of a method for the transference of results of elasticity or failure tests from models to actual aircraft. Using the principal factors to determine the loads on aeronautical structures, the law of structural similarity is derived.

Aerodynamic Influence Coefficients for an Oscillating Finite Thin Wing in Supersonic Flow. Ta Li. (*IAS 23rd Annual Meeting, New York, Jan. 24–27, 1955, Preprint 500.*) *J. Aero. Sci.,* July, 1956, pp. 613–622. Development of a method for calculating influence coefficients in which the pressure difference is approximated by dividing the region of integration into a mesh of congruent rectangles with diagonals parallel to the Mach lines.

Theoretical Aerodynamic Properties of Vanishing Aspect Ratio Harmonically Oscillating Rigid Airfoils in a Compressible Medium. Bernard Mazelsky. *J. Aero. Sci.,* July, 1956, pp. 639–652. Extension of the Garrick results to the compressible case, with the solutions for the velocity potential determined from the two-dimensional wave equation instead of the Laplace equation. Numerical results are obtained for the complete reduced frequency range.

Aeroelastic Problems of Low Aspect Ratio Wings. IV—Application of the Structural and Aerodynamic Matrices to the Solution of the Flutter Problem. J. Leyds. *Aircraft Eng.,* May, 1956, pp 166, 167.

Numerical Integration Methods for Supersonic Wings in Steady and Oscillatory Motion. B. Etkin. *UTIA Rep. 36,* Nov., 1955. 53 pp. 14 refs. Extension and review of the Etkin and Woodward results for the case of thin lifting wings in steady flow, with application of the steady flow equations to an untwisted wing having a symmetrical section at zero incidence, and derivation of summation formulas suitable for computation by digital computers.

Flutter Calculation of Wing with an Elastically Supported Concentrated Weight. Kichiji Nishino. *J. Japan Soc. Aero. Eng.,* Apr., 1956, pp. 1–7. Investigation of the effect of a spring-mounted, concentrated mass on the bend-torsion flutter characteristics of a two-dimensional airfoil.

The Flexure-Torsion Flutter of Cambered Aerofoils in Cascade. A. H. Craven and I. Davidson. *Coll. of Aeronautics, Cranfield, Rep. 95,* Dec., 1955. 36 pp. Results of a series of tests on the flexure-torsion flutter of cascade airfoils of 30° and 45° camber, covering stagger angles between −30° and +30°, and gap chord ratios up to 1.5 at a Reynolds Number of 1×10^5 based on airfoil chord. The critical flutter speeds and frequencies

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The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel. John W. Miles. *J. Aero. Sci.*, July, 1956, pp. 671–678. 14 refs. Analysis of the disturbance produced by an oscillating airfoil in a two-dimensional supersonic wind tunnel. The solution is presented either as an expansion in the fields of the image, or in the natural modes or guided waves of the tunnel.

A Technique for the Measurement of Pressure Distribution on Oscillating Aerofoils, with Results for a Rectangular Wing of Aspect Ratio 3.3. W. G. Molyneux and F. Ruddlesden. *Gt. Brit., ARC CP 233*, 1956. 24 pp. BIS, New York. $0.63.

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Bending Vibrations of Variable Section Beams. E. T. Cranch and Alfred A. Adler. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 103–108. Application of the simple beam theory to obtain solutions for the vibration of beams having rectangular cross section with (a) linear depth and any power width variation, (b) quadratic depth and any power width variation, (c) cubic depth and any power width variation, and (d) constant depth and exponential width variation. Also includes an investigation of the vibration of compound beams and a discussion of several cases of free double wedges with various width variations.

Influence of Secondary Inertia Terms on Natural Frequencies of Rotating Beams. J. L. Bogdanoff. *J. Appl. Mech.*, Dec., 1955, pp. 587–591. 12 refs.

Free Vibrations of Thin Cylindrical Shells Having Finite Lengths with Freely Supported and Clamped Edges. Yi-Yuan Yu. (*ASME Natl. Conf., Troy, June 16–18, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 547–552. Investigation based on a set of three differential equations, derived similarly to those obtained by Donnell for bending and buckling problems. A simplifying assumption is introduced to solve frequency equations for cylindrical shells with back edges freely supported, with both edges clamped, and with one freely supported and one clamped edge.

Nonlinear Dynamic Coupling in a Beam Vibration. P. H. McDonald, Jr. (*ASME Natl. Conf., Troy, June 16–18, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 573–578. Investigation of the vibration of a uniform beam with restrained hinged ends and with arbitrary initial conditions of motion.

The Free Oscillations of a Buckled Panel. W. D. Hayes and J. W. Miles. *Quart. Appl. Math.*, Apr., 1956, pp. 19–26. Analysis using nonlinear equations of motion of a buckled, two-dimensional panel formulated in dimensionless form, and a Fourier expansion for the elimination of the space variable. Approximate solutions are obtained for a period of free oscillation under the assumption of two degrees of freedom, one of which is eliminated by the buckling constraint.

On the Nonlinear Oscillations of Viscoelastic Plates. A. Cemal Eringen. (*ASME Natl. Conf., Troy, June 16–18, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 563–567. 18 refs. Development of a second-order theory by integrating the equations of motion of the three-dimensional finite oscillation theory across the plate thickness.

Forced Vibration of a Clamped Rectangular Plate in Fluid Media. Gordon C. K. Yeh and Johann Martinez. (*ASME Natl. Conf., Troy, June 16–18, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 568–572. Analysis based on the assumptions that the plate separates two different fluid media and that the vibration is excited by a simple plane wave of high frequency normally incident from one side of the plate. Lagrange equations of motion are used and solved for plate deflection by series expressions.

Determination of Natural Frequencies of Continuous Plates Hinged Along Two Opposite Edges. A. S. Veletsos and N. M. Newmark. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 97–102. 10 refs. Development of a numerical procedure for computing the undamped natural frequencies of bending vibration of rectangular plates hinged along two opposite edges and continuous over rigid supports transverse to the hinged edges.

Influence of Large Amplitudes of Flexural Motions of Elastic Plates. George Herrmann. *U.S., NACA TN 3578*, May, 1956. 45 pp. 21 refs. Derivation of a set of plate equations of motion for an isotropic material obeying Hooke's linear law, based on fundamental equations of the general three-dimensional nonlinear theory of elasticity for the case of small elongations and shears, but moderately large rotations.

Ortotropowe Płyty Prostokątne o Brzegach Swobodnych. Zbigniew Kączkowski. *Arch. Mech. Stosowanej* (Warsaw), No. 4, 1955, pp. 458–482. In Polish, with summaries in English and Russian. Development of a method to determine the frequency of free vibrations and the critical normal loads in the case of a rectangular plate with supports located in the corners only, using Nowacki's theorem. This theorem shows that the sum of a double trigonometric series does not necessarily satisfy the boundary conditions of a simple support, but is satisfied by each particular term of the series.

Vibration and Stability Problems of Beams Treated by Matrices. K. Marguerre. *J. Math. & Phys.*, Apr., 1956, pp. 28–43. OSR-sponsored investigation of the matrix method for solving the differential equation of a vibrating beam and for the related problem of the vibrating column.

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Air Traffic Facts. A. D'Arcy Harvey. (*IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 592.*) *Aero. Eng. Rev.*, July, 1956, pp. 58–62.

Air Commerce; A Study of Aircraft Exports: Historical Development; Present Realities. Victor L. G. Gore. *Aircraft Prod.*, June, 1956, pp. 236–239.

Airplane Design

Aircraft Fatigue. H. Giddings. *J. RAeS*, May, 1956, pp. 313–322. Analysis of the fatigue phenomena, taking into account loading conditions, materials, and design. Includes a discussion of fail-safe design and fatigue testing.

Flight Loads. R. H. Sandifer. *J. RAeS*, May, 1956, pp. 301–306. Discussion of present and future flight load requirements, taking into account the flight envelopes for symmetric maneuvers, asymmetric maneuvers such as rolling and yawing, gust loads, control surface loads, engine and propeller loads, and cabin pressure loads. Further includes future requirements to be defined covering kinetic heating, speed requirements at high altitudes, boundary suction and jet flaps, and wings for supersonic flight.

The Presentation of Fatigue Data for Fatigue Life Calculations. C. L. Bore. *J. RAeS*, May, 1956, pp. 331–346. 10 refs. Test results presented as a fatigue endurance chart where static failure is regarded as fatigue failure in one cycle of loading. Chart shows the effects of mean stress, residual stress, and pretension.

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Air Conditioning & Pressurization

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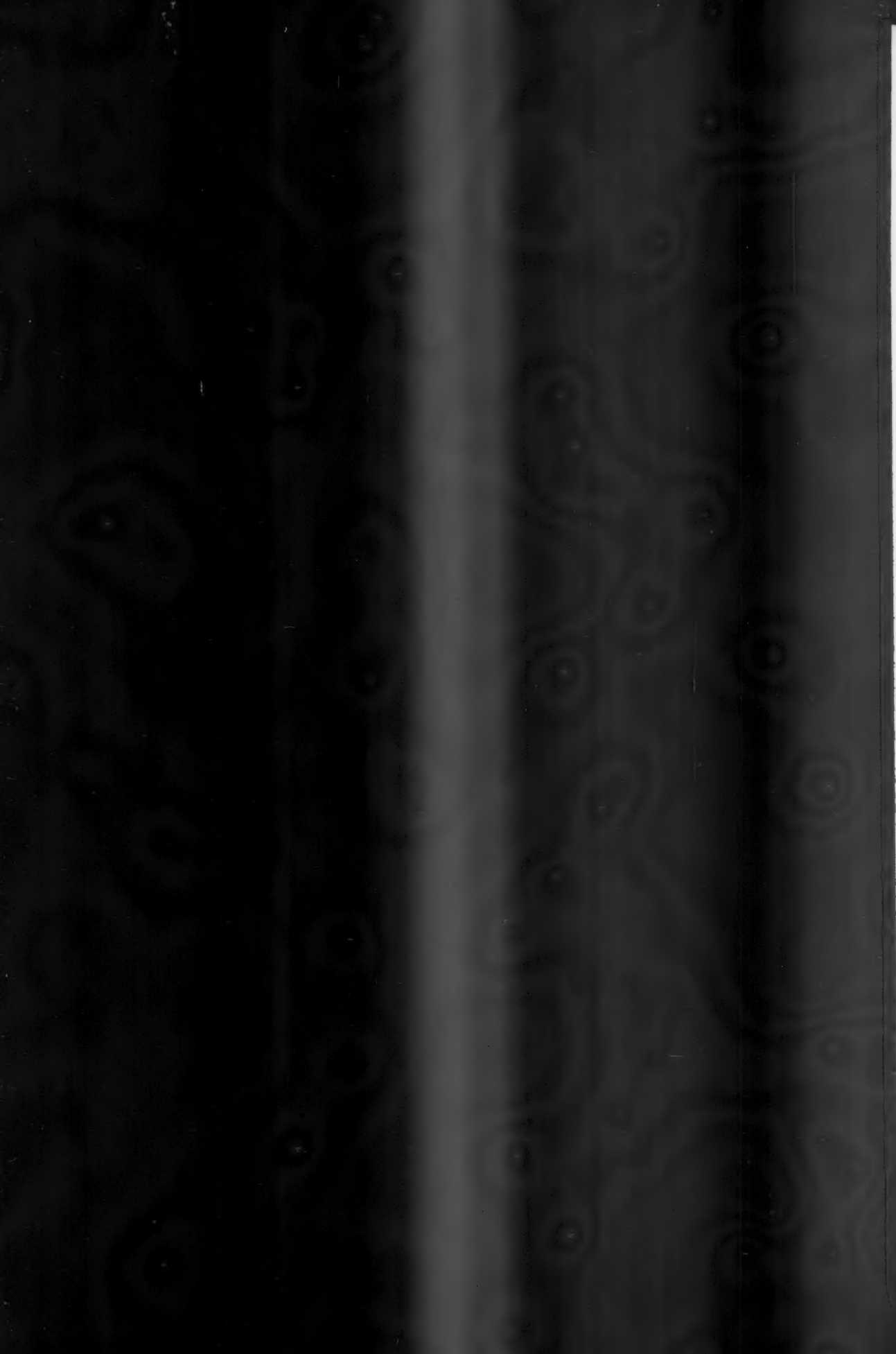
Pressure-Cabin Design; A Discussion of Some of the Structural Problems Involved, with Suggestions for Their Solution. Appendix A—**Neutral Hole in Plane Sheet with Equal Principal Stresses.** Appendix B—**Design of Reinforcing Rings for Circular Holes—Useful Data Derived from Standard Formulae.** Appendix C—**Membrane Forces in a Surface of Revolu-**

(Continued on page 130)



INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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ACOUSTICS, SOUND, & NOISE

AN ANALYSIS OF BUZZING IN SUPERSONIC RAM JETS BY A MODIFIED ONE-DIMENSIONAL NONSTATIONARY WAVE THEORY. R. L. Trimpi. US, NACA TN 3695, July, 1956. 72 pp. Derivation of a theory applicable to the buzzing problem obtained by modification of the one-dimensional, unsteady-flow theory, and introducing specified assumptions which greatly facilitate the computational efforts without impairing the usefulness of the theory for this type of flow. Theoretical computations of the pressure-time curves made on this basis for one supersonic-diffuser configuration with two different subsonic-duct lengths, agree closely with experimental records. Entrance and exit mass-flow-time curves, as well as wave diagrams, are also computed for these configurations.

SUPERSONIC BANGS. II. P. Sambasiva Rao. Aero. Quart., May, 1956, pp. 135-155. Extension of the nonlinear theory of supersonic bangs, for a body accelerating along a straight path, to include curved paths. Results indicate that the only essential effect of the curvature of the path is in the modification of the acceleration component to include a term due to the transverse acceleration. The strength of the bow shock is obtained, and the effect of the curvature of the path is found to be more pronounced at points on the inside of the curve and to grow as the distance from the body increases. The shock strength may be predicted with an error of less than 5% at distances of the order of a hundred body-lengths.

AERODYNAMICS

Aerothermodynamics

THE PROBLEM OF AERODYNAMIC HEATING. E.R. Van Driest. IAS Natl. Summer Meeting, Los Angeles, June 18-21, 1956, Preprint 645. 31 pp. 25 refs. Members, $0.65; nonmembers, $1.00. Analysis of the rate of heat-transfer to the surface of high-speed vehicles. The variable parameters for heat transfer are the recovery factor and the Stanton Number, with the latter being the most critical. Calculations are made for a flat plate and a blunt body, for the cases of laminar and turbulent flow. For laminar flow on a flat plate both the recovery factor and the Stanton Number can be determined exactly by solving the momentum and the energy equations simultaneously. For turbulent flow the recovery factor is approximated by making simplified assumptions for shear and velocity distribution; the Stanton Number is found by using a derived friction coefficient and a Reynolds analogy factor. For blunt bodies the solution is obtained by the same means, except that a form factor for the body is included in the general equation for the heat transfer. Also includes a discussion of the effects of boundary-layer control by surface cooling on performance and structural design of aircraft. Further includes suggested future areas of research.

PROBLEMS OF AEROPHYSICS IN THE HYPERSONIC REGION. J. W. Bond, Jr. Aero Dig., June, 1956, pp. 21-25. Consideration of the effects of the state of air in the shock region, the flow field and transport properties, and the shock front and boundary layer on a hemisphere-cylinder which is assumed to absorb heat at a sufficiently high rate to prevent melting and erosion, with all the heat assumed to be absorbed either by the object or by the air.

THE THERMAL PROBLEMS OF HIGH-SPEED FLIGHT AND THE GENERAL ELECTRIC AIRCRAFT COOLING PROGRAM. J. W. Rizika. ASME Semi-Annual Meeting, Cleveland, June 17-21, 1956, Paper 56--SA-24. 11 pp. Review of the problems including aerodynamic heating, internal heat sources, and heat sinks, with a discussion of the objectives and some of the conclusions. The scope of the work involves studies of criteria, engine components, turboconditioner controls, individual conditioning cycles and systems, and aircraft applications. Results indicate that each particular aircraft conditioning application requires an espe-

cially-designed turboconditioner system with criteria, such as cooling loads and temperature levels, established by the aircraft manufacturer. The insulation of components requiring cooling will keep the aircraft cooling load, except for the engine, relatively independent of Mach Number, and the ram air, whose temperature rise is approximately proportional to the square of the Mach Number, will remain the primary heat sink, requiring more complicated heat pumps to overcome great temperature differentials.

SURFACE-PROTECTION AND COOLING SYSTEMS FOR HIGH-SPEED FLIGHT. D.J. Masson and Carl Gazley, Jr. IAS Natl. Summer Meeting, Los Angeles, June 18-21, 1956, Preprint 638. 19 pp. 13 refs. Members, $0.50; nonmembers, $0.85. Discussion of cooling systems for aircraft under transient and continuous heat inputs. Weight requirements for these systems increase with flight equilibrium temperature, and with the time of flight. For the lower range of flight equilibrium temperatures or lower transient heat loads, thickened metallic skin appears to be the most efficient means of countering the surface aerodynamic heating, and for cooling internal equipment, the ultimate dissipation to atmospheric air seems the most suitable. For higher flight equilibrium temperatures, surface protection is best obtained by insulation of the outer structure and internal cooling, or by means of a transpiration or mass transfer system. Internal cooling in this range is accomplished by an expendable vaporizing coolant, or by the thermal capacity of the equipment and structure themselves.

EFFECT OF PRANDTL NUMBER ON THE HEAT TRANSFER PROPERTIES OF A TURBULENT BOUNDARY LAYER WHEN THE TEMPERATURE DISTRIBUTION ALONG THE WALL IS ARBITRARILY ASSIGNED. C. Ferrari. ZAMM, Mar.-Apr., 1956, pp. 116-135. 16 refs. Derivation of formulas for the Nusselt Number from a determination of the influence of the Prandtl Number on the recovery factor, taking into account the existence of a buffer zone between the laminar sub-layer and the truly turbulent layer, with experimental verification. Includes determination of: the primary part of the spot difference function; the recovery factor; and the heat transfer characteristics when the temperature distribution along the wall exhibits a plateau-like jump. The results may be considered as an extension of the Prandtl-Taylor and von Kármán derivations for the analogous case in which the fluid is assumed to be incompressible and the temperature along the wall is constant.

A REVIEW OF HEAT TRANSFER DATA ON THE EVAPORATION OF LIQUIDS AT SUB-ATMOSPHERIC PRESSURES. T.D. Patten. Gt. Brit., RAE TN Mech. Eng. 216, Apr., 1956. 22 pp. 24 refs. Presentation of available data, particularly with regard to water and with special attention given to those theories of heat transfer during boiling which are likely to be encountered in practice, and to the existing correlations of experimental results. The study is directed toward the solution of the problem of cooling at high aircraft speeds through the possibility of rejecting the heat to a liquid as its latent heat of evaporation. Includes a graph compiled from existing data and applicable as a rough guide to the heat transfer properties of boiling water. Two recommendations are made for further research, both concerned with nucleate boiling: a) the confirmation and augmentation at very low pressures of the data of Cryder and Finalborgo, together with observation of the bubble size and formation, in order to improve the existing correlations; and b) a study of the evaporation of liquids within narrow vertical passages at low pressures to determine the influence of heat transfer of the interference between vapor bubbles and the passage walls.

Boundary Layer

BOUNDARY LAYER. L.G. Loitsianskii. (Translation from Mechanics in the USSR Over Thirty Years, 1917-1947, pp. 300-320.) US, NACA TM 1400, May, 1956. 29 pp. 70 refs. Comprehensive bibliography covering research in USSR, with a review of the most important results obtained in the development of the theory of the boundary layer. The analysis of the problems encountered includes that of boundary layer and resistance in compressible gas at large velocities, certain special aspects of the theory of boundary layer in incompressible fluid, turbulent boundary layer in plane-parallel motion of incompressible fluid, and laminar boundary layer for the case of plane-parallel motion of incompressible fluid. The one-parameter method applied for computing the flow of wing profiles and other cylindrical bodies in two-dimensional flow is discussed, and the special problem of the decrease of friction due to changes in the physical constants of the liquid or gas is analyzed.

THE LAMINAR BOUNDARY LAYER ON OSCILLATING PLATES AND CYLINDERS. M.B. Glauert. J. Fluid Mech., May, 1956, pp. 97-110. Theoretical investigation of the two-dimensional, laminar boundary layer on an infinite plate normal to an oncoming stream, the plate making transverse oscillations in its own plane, and derivation of a solution, containing the frequency of oscillation as a parameter and depending on a single, ordinary differential equation which satisfies the full Navier-Stokes equations. Series methods are used to evaluate the solution for small and large values of the frequency, and enough terms are calculated to give the solution with satisfactory accuracy over the whole frequency range. It is shown that the results for a flat plate can be used to describe the boundary layer in the neighborhood of the front stagnation point for a cylinder of arbitrary section making transverse or rotational oscillations. Difficulties arising in the extension of the solution to cover the remainder of the cylinder are discussed, and an estimate is made of the fluctuating torque on a circular cylinder making transverse oscillations.

METHODES DE CALCUL DE LA COUCHE LIMITE LAMINAIRE BIDIMENSIONNELLE EN RÉGIME COMPRESSIBLE. E. A. Eichelbrenner.

France, ONERA Pub. 83, 1956. 135 pp. 28 refs. In French. Development of methods for the calculation of the laminar three-dimensional boundary layer in a compressible fluid, with an analysis of the initial conditions related to the problem of the boundary layer behind a detached shock wave and with a discussion of mathematical aspects of the problem. Two methods are analyzed: (a) iterative method based on the Moeckel criterion for the approximate calculation of the position and the curve of a detached shock wave in front of an obstacle and (b) method based on the nonsimplified Navier-Stokes system; both methods are compared with that of Pohlhausen.

GRENZSCHICHTUNTERSUCHUNGEN AN ZWEI SCHIEBENDEN, UNENDLICH LANGEN FLÜGELN IN INKOMPRESSIBLER STRÖMUNG. K. Nickel. DFL Inst. für Aero. Bericht No. 56/12, Apr. 18, 1956. 41 pp. In German. Investigation of the boundary layer on two yawed, infinitely long airfoils in incompressible flow. The Truckenbrodt method is used to calculate laminar and turbulent boundary layers on two experimental airfoils, one having a standard and the other a laminar cross section. A comparison with theoretical results indicates that the shape of the wing has little influence on the displacement of the boundary layer. Computed results compared with those experimentally obtained show good agreement.

OBLICZANIE CHARAKTERYSTYCZNYCH WIELKOSCI WARSTWY PRZYŚCIENNEJ BURZLIWEJ NA PODSTAWIE WYNIKÓW BADAŃ DOŚWIADCZALNYCH. Wojciech Brzozowski. Arch. Budowy Maszyn (Warsaw), No. 2, 1956, pp. 165-189. In Polish. Description of a theoretical method of calculating the characteristic quantities of the turbulent boundary layer by using Bury's formula and the mean gradient of static pressure along the perimeter of the section. The method is based on the results of an experimental investigation on a model of a blade with an NACA 0012 section. The quantities calculated include the loss of the impulse (ϑ) of the turbulent boundary layer, and the parameter H, and the results obtained are compared with the experimental results of Doenhoff and Teterwin, Fage, Falkner and Walker, with good agreement. Includes determination, on the basis of numerous measurements, of the relation of parameter $H = f(H)$ in order to calculate the efficiency of two-dimensional cascades of blades used in helicopters, and comparison of results with those previously obtained indicates deviations of 5 to 6%. The method is primarily applicable to airflows with pressure gradients similar to those measured under similar conditions.

UNTERSUCHUNGEN UBER DIE ABHÄNGIGKEIT DES UMSCHLAGES LAMINAR-TURBULENT VON DER OBERFLÄCHENRAUHIGKEIT UND DER DRUCKVERTEILUNG. E.G. Feindt. DFL Inst. Aero., Berich No. 56/10, Apr. 17, 1956. 167 pp. In German. Experimental investigation to determine the manner in which the location of the laminar-turbulent transition point depends on pressure gradient and surface roughness in the case of flow along a wall with three-dimensional roughness elements and flow along a wall with a two-dimensional individual roughness element. Results of measurements show that the separation between the experimentally determined transition point and the aerodynamic center (obtained from the stability theory of laminar flow) depends on the grain size of an evenly distributed roughness. Further includes theoretical calculation of the nature of the boundary layer coefficient using the Scholz method. A comparison with experimental values shows good agreement.

Control Surfaces

MIXING AND THE JET FLAP. B.S. Stratford. Aero. Quart., May, 1956, pp. 85-105. Study of the problem of discrepancy in thrust between idealized theory and experimental results attributed to the mixing with the surrounding flow of the thin two-dimensional jet, while still in close proximity to the airfoil. The effect of the mixing can be calculated to a first approximation from a formula derived from first principles. Results show that the use of by-pass engines would improve the thrust characteristics and that a shrouded jet flap gives a better thrust recovery at take-off than the pure jet flap.

SOME FURTHER JET FLAP EXPERIMENTS. N.A. Dimmock. Gt. Brit., NGTE Memo. M.255, May, 1956. 70 pp. Extension of Dimmock's results of experiments on a two-dimensional airfoil with a 12.5% thick elliptical cross section with a narrow full span jet slot, to the same type of airfoil with the jet deflection 58.1° from the chord line. Tests include photographic recording of the flow pattern in the vicinity of the airfoil, as revealed by smoke filaments, and measurements of the forces and moments acting on the model. Results largely confirm those previously obtained and support the Davidson-Stratford theory for a simple jet flap airfoil with or without incidence. The photographic recordings indicate that with the airfoil at zero incidence the entrainment of the mainstream by the jet is sufficient to cause the mainstream to rejoin the upper surface after separation at the leading edge, even with a full chord separation bubble. Further results indicate that the reduction of lift and thrust and the movement aft of the center-of-lift position due to ground interference are substantial at small ground clearances.

Fluid Mechanics & Aerodynamic Theory

ON THE STEADY FLOW PAST A SPHERE AT HIGH REYNOLDS NUMBER USING OSEEN'S APPROXIMATION. K. Stewartson. Philos. Mag., 8th Ser., Apr., 1956, pp. 345-362. 15 refs. Results of a shorter derivation of the Oseen approximation indicate that a boundary layer is formed on the forward side and a wake extending to infinity on the rearward side. Inside the wake, which is bounded by a circular cylinder with its generators parallel to the undisturbed direction of the streamlines, the fluid at infinity is moving towards the sphere,

while outside it is moving away with the undisturbed velocity, and there is a shear layer at the cylinder.

THE SLENDER ELLIPTIC CONE AS A MODEL FOR NON-LINEAR SUPERSONIC FLOW THEORY. M.D. Van Dyke. J. Fluid Mech., May, 1956, pp. 1-15. 19 refs. Derivation of the second-order slender-body solution for an unyawed elliptic cone in supersonic flow to serve as a basis for a critique of various approximations in compressible flow theory, including slender-body, linearized, first- and second-order thin-wing theories; edge corrections; and the method of linearized characteristics.

LOI DES AIRES DES COUPLES. R. Legendre. La Recherche Aéronautique, Mar.-Apr., 1956, pp. 3-8. In French. Analysis of the law of coupled areas. The supersonic flow of a compressible fluid around a slender body follows the law of quasi-incompressibility on Mach cones, which makes it possible to establish that the resistance depends essentially on the law of coupling areas or on the distribution of transversal sections of the body as function of the abscissa. A modification applicable to the study of the flow around bodies at supersonic speeds is obtained by a substitution to coupled areas of areas included in the projection of a transversal surface of body intersections by Mach cones.

BERICHT ÜBER EINE NÄHERUNGSTHEORIE DER STRÖMUNG UM ROTATIONSKÖRPER OHNE ANSTELLUNG BEI MACHZAHL EINS. F. Keune. DVL Bericht No. 3, Dec., 1956. 23 pp. Westdeutscher Verlag, Köln & Opladen, DM 8.80. In German. Development of an approximation theory of flow around bodies of revolution at M=1 compared with semi-spindle measurements. The Oswatitsch nonlinear characteristics method is used to calculate the flow within and beyond the speed maximum for bodies with falling velocities.

DRIFT. M. J. Lighthill. J. Fluid Mech., May, 1956, pp. 31-53. Theoretical investigation leading to a simple expression for the secondary velocity field in the flow past an infinite cylinder of any cross section, with the upstream velocity normal to its axis and increasing linearly with distance along the axis. Includes computation and illustration of the drift past a sphere and tabulation of the secondary vorticity field in shear flow past a sphere. Also includes a detailed study of the asymptotic form of the secondary velocity field in the flow past any body, based on the Darwin result for hydrodynamic mass. The Cauchy-Helmholtz-Kelvin result, indicating that the vortex lines move with the fluid while the magnitude of the vorticity changes in proportion to the local stretching of the vortex lines, is combined with the study of drift of material surfaces to deduce the method of alteration of the vorticity in a weakly-sheared flow in the presence of an obstacle, as a result of deformation of vortex lines by the irrotational component of the flow about the obstacle.

DIFFRACTION OF A WEAK SHOCK WITH VORTEX GENERATION. Nicholas Rott. J. Fluid Mech. May, 1956, pp. 111-128. 12 refs. OSR-supported theoretical investigation of the region of finite vorticity near the edge of a diffracting wedge, a dimensional analysis of the dependence of the circulation and the velocity of the vortex region on the pulse strength, and an estimate of the magnitude of these quantities obtained by replacing the vortex region by a single concentrated vortex. Includes a discussion of the theoretical conditions at the sharp edge compared with observations of real fluid behavior, and an account of the theory of the core of the spiral vortex sheet in a perfect fluid. A potential ϕ is assumed in treating the diffraction problem with vortex separation in the linearized approximation of compressibility, the Mach Number is assumed to be small compared to unity, and viscosity and heat conduction are neglected.

APPLICATION OF SCATTERING THEORY TO THE MEASUREMENT OF TURBULENT DENSITY FLUCTUATIONS BY AN OPTICAL METHOD. Appendix A---RELATIONSHIP BETWEEN DIELECTRIC FLUCTUATIONS AND DENSITY FLUCTUATIONS FOR AIR. Appendix B---TELEPHOTOMETER EQUATION FOR THE CASE OF A GAUSSIAN CORRELATION COEFFICIENT. H. A. Stine and Warren Winovich. US, NACA TN 3719, June, 1956. 21 pp. 10 refs. Description of the method which is based on the hypothesis that the turbulent field can be defined uniquely in terms of the scattered electromagnetic field which arises when a plane wave passes through the turbulence, and which is particularly applicable to turbulence measurements in compressible flows, in that it responds only to density fluctuations, as opposed to the mixed-response signal of the hot-wire anemometer. The method also eliminates the need for a probe and requires a minimum of electronic circuitry.

EIN VERFAHREN ZUR UNTERSUCHUNG DES AUSTAUSCHVORGANGES IN VERWIRBELTEN STRÖMUNGEN HINTER KÖRPERN MIT ABGELÖSTER STRÖMUNG. A.W. Quick. DVL Bericht No. 12, Mar., 1956. 34 pp. Westdeutscher Verlag, Köln & Opladen, DM 8.70. In German. Development of a method for the solution of the exchange process between the outside flow and the flow in the vortex behind blunt bodies, and determination of the mechanism of the flow behind bodies with detached flow and of the turbulent mixing in free jets.

Internal Flow

BEITRAG ZUR BERECHNUNG VON SEKUNDÄRSTRÖMUNGEN. E. Becker. Max.-Planck-Inst. für Strömungsforschung, Mitteil. No. 13, 1956. 85 pp. 34 refs. DM 8. In German. Investigation of the rotationally symmetric flow of a real incompressible fluid between two fixed parallel surfaces where the streamlines of the mean flow form concentric circles. The centrifugal forces caused by the curvature of the streamlines are followed by secondary flows. The secondary flows are determined, taking into account experimental aspects covering turbulent flows and theoretical aspects of

the problem which include the laminar case. For the laminar case an iterative solution is obtained for the Navier-Stokes equation, in which the velocity components in potential series are developed according to a parameter K, and the Dean calculation of the flow through a curved pipe is taken into account.

AN ANALYSIS OF THE PERFORMANCE OF AN AXIAL-FLOW COMPRESSOR AT LOW REYNOLDS NUMBER. R. L. Sohn. J. Aero. Sci., Aug., 1956, pp. 741-746, 791. Theoretical study of compressor performance taking into account the behavior of the boundary layer attached to the blades. The theory suggests that the blade boundary layer forms a laminar separation bubble shortly downstream of the point of minimum pressure, reattaching itself in turbulent form after the transition has taken place. At very low Reynolds Numbers the separated boundary layer is so stable that transition fails to take place upstream of the blade trailing edge. Under these conditions, the fluid turning accomplished by the blade decreases abruptly, and the blade losses increase with an attendant loss in efficiency. A critical Reynolds Number is described and verified by test data. An empirical method, based on cascade data, is derived for predicting the critical number.

A POTENTIAL FLOW SOLUTION WITH APPLICATIONS IN STUDIES CONCERNING MASS ADDITION ALONG THE BOUNDARIES OF THE FLOW. J. L. Potter and N. M. Shapiro. USRA OML Rep. 2R16F, June 18, 1956. 17 pp. Analysis of a system where mass is added from the opposite walls of a two-dimensional container or chamber which is closed at one end and open at the other, using potential flow methods. Resulting streamline patterns and velocity distributions are shown for two examples where parallel and divergent walls are compared.

ON THE WAKE ENERGY OF MOVING CASCADES. N. H. Kemp and W. R. Sears. J. Appl. Mech., June, 1956, pp. 262-268. OSR-supported analysis of the rate of energy transfer into kinetic energy of the vortex wakes for unsteady two-dimensional flow in cascades of thin airfoils, as applied to an elementary compressor stage consisting of two rows of blade in relative motion. Results indicate that the magnitude of the energy transfer is small, amounting to less than 1% of the energy absorbed by the rotor. For a two-stage rotor the cross-induced energy transfer may be negative. Energy transfer of the upstream row is many times greater than that of the downstream row, owing to the disparity in the magnitudes of the respective induced circulation fluctuations.

A STUDY OF THE HIGH-SPEED PERFORMANCE CHARACTERISTICS OF 90° BENDS IN CIRCULAR DUCTS. J. T. Higginbotham, C. C. Wood, and E. F. Valentine. US, NACA TN 3696, June, 1956. 28 pp. Investigation of the performance of four bends in ducts of constant diameter with ratios of radius of curvature to diameter of 0.75, 1.00, 2.50, and 4.00 over a range of inlet Mach Numbers extending up to the choking condition for both thin and thick inlet boundary layers. Determination of the variation of the measured longitudinal static-pressure gradients at low speed from those predicted by two-dimensional, incompressible potential-flow theory. Results indicate that the inlet boundary-layer thickness decreases the choking Mach Number by a very small amount for each of the elbows and has little effect on the other performance parameters.

EINFLUSS DER BOHRLOCHGRÖSSE AUF DIE ANZEIGE DES STATISCHEN DRUCKES BEI VERSCHIEDENEN REYNOLDSZAHLEN. A. K. Ray. Ing.-Arch., No. 3, 1956, pp. 171-181. In German. Study for the determination of the error and error sources in the calculation of the flow between perforated parallel walls, whose presence distorts the flow causing a change in the pressure. The influence of the hole diameter on the static pressure at different Reynolds Numbers is calculated.

THE OSCILLATIONS OF A SUPERSONIC GAS JET EMBEDDED IN A SUPERSONIC STREAM. D. C. Pack. J. Aero. Sci., Aug., 1956, pp. 747-753, 764. Theoretical analysis, based on the linearized equation of steady motion in gas dynamics, of both two-dimensional and axially symmetrical jets. The analysis of the oscillations for the two-dimensional case sets up the procedure and presents the findings of Pai and Kawamura in a general form, while illustrating some new features. A comparison is made between the reflection and transmission phenomena in the two-dimensional and axially-symmetrical cases, and the flow near to and at a large distance from the orifice from which the jet flows is examined. For both types of jets it is assumed that pressure changes are small everywhere, and both heat conduction and viscosity are neglected. Results indicate that the ultimate change in the width of an axially symmetrical jet is just one-half that of the two-dimensional jet under the same conditions at the orifice. Some remarks are made concerning the singularities within the jet as well as those which occur in the boundary gradient. In axially symmetrical jets it is found that the displacement of the jet boundary may be divided into three parts: the first is a constant (the asymptotic width of the jet); the second may be expressed as an infinite integral; and the third is obtained as the superposition of an infinite number of damped harmonic oscillations. It is noted that the general problem of the behavior of a supersonic jet emerging into a medium in supersonic motion represents the motion of the flow of exhaust gases from the rocket motor relative to a rocket in supersonic flight.

VELOCITY DISCONTINUITY INSTABILITY OF A LIQUID JET. B. Dunne and B. Cassen. J. Appl. Phys., June, 1956, pp. 577-582. Theoretical and experimental investigation of the origins and behavior with time of the velocity discontinuity instability which occurs when the liquid reservoir from which the jet issues is subjected to

shock wave pressure, causing a discontinuous increase in jet velocity, with a thin disc of liquid, normal to the jet axis, appearing at the discontinuity. Experimental work consists of four successive quarter-microsecond exposures obtained by a shadowgraph technique, using jets of water and ethanol in external atmospheres of air and helium, in an interval of thirty microseconds. The assumptions of the modified Taylor-Birkhoff theory are used in an analytic discussion considering two velocity functions: (1) a jet with a particle velocity at the aperture which is a step function of time, and (2) a jet with a velocity which has a transient rise followed by a linear decay with time. The velocity gradient in the jet is shown to have two effects on the disc shape: the successive elements with lower velocities cause the junction to move more slowly than the disc peripheral elements; and the successive elements flowing from the junction have a backward velocity component, causing a stretching of the jet which results in a reduction of cross-section.

ON THE THRUST DUE TO AN AIR JET FLOWING FROM A WING PLACED IN A WIND TUNNEL. L. C. Woods. J. Fluid Mech., May, 1956, pp. 54-60. Derivation of a theory for correcting the measured thrust on the wing due to a high speed jet emerging from it in order to obtain the infinite stream value. The theory establishes that the ideal thrust is almost independent of the jet exit angle.

Stability & Control

INVESTIGATION OF LATERAL CONTROL NEAR THE STALL; ANALYSIS FOR REQUIRED LONGITUDINAL TRIM CHARACTERISTICS AND DISCUSSION OF DESIGN VARIABLES. F. E. Weick and Norman Abramson. US, NACA TN 3677, June, 1956. 91 pp. 12 refs. Development of analytical means for the estimation of the elevator deflection required to trim in steady longitudinal flight and for the demonstration in a quantitative manner of the effects on longitudinal trim of changes of some design parameters. Simplified methods and semi-empirical data are summarized to provide analytical procedures applicable to preliminary design. Two light aircraft are analyzed quantitatively for both power-on and power-off conditions in order to demonstrate the use of these methods and to provide a comparison with flight-test results. Calculated values are presented for both aircraft to demonstrate the qualitative effects of changes in some variables and the effects of power. Results indicate that these methods can result in a design in which the maximum up-elevator deflection may be maintained within the highest value that will provide satisfactory damping in roll and reliable lateral control under all flight conditions, while, at the same time, adequate longitudinal control is available.

INVESTIGATION OF LATERAL CONTROL NEAR THE STALL; FLIGHT TESTS WITH HIGH-WING AND LOW-WING MONOPLANES OF VARIOUS CONFIGURATIONS. F. E. Weick and H. N. Abramson. US, NACA TN 3676, June, 1956. 34 pp. Results indicate that for all the light aircraft tested adequate lateral control is available up to a critical angle of attack which is within 2° of the angle of attack for maximum lift. The elevator deflection required to make a three-point landing and the elevator deflection required to trim at this condition are determined with power off and power on for each aircraft.

Wings & Airfoils

APPLICATION DE LA THÉORIE DES MOUVEMENTS HOMOGÈNES AU CALCUL DES EFFETS DE PORTANCE POUR DES AILES EN FLÈCHE EFFILÉES. M. Fenain and D. Vallée. La Recherche Aéronautique, Mar.-Apr., 1956, pp. 17-25. In French. Application of the theory of homogeneous motion to the calculation of the effects of lift on delta wings. Also includes calculation of the effects of spin whose law depends on two parameters, used as an illustrative example of the application.

LIMITES D'APPLICATIONS DE LA THEORIE DE LA LIGNE PORTANTE AU CALCUL D'AILES D'AVIONS MUNIES DE SPOILERS. A. Fauquet. Inst. Méc. Fluides, Lille, France, IMFL No. 56 HR, Mar. 30, 1956. 107 pp. In French. Application of the lifting line theory to the calculation of airfoils equipped with spoilers, with an analysis of its limitations. Extension of previously obtained results on rectangular wings and of the calculation of their lift, drag, and rolling and yawing moments using the Prandtl lifting line theory, to airfoils of aspect ratios 5, 4, and 3, and to spoilers at a distance from the leading edge of 10, 20, 30, 40, 60, and 80% chord. Comparison of theoretical and experimental data indicates that lift, drag, and yawing moments can be obtained for spoilers at over 35% from the leading edge and for aspect ratios equal to or higher than 3. The calculation of the rolling moment is limited to spoilers situated at more than 60%.

DER GEWOLBTE UND VERWUNDENE TRAGFLÜGEL OHNE DICKE IN SCHALLNÄHE. F. Keune. DVL Bericht No. 13, Apr., 1956. 30 pp. 15 refs. Westdeutscher Verlag, Köln & Opladen. In German. Derivation of aerodynamic data for cambered and twisted airfoils as an extension of the Jones theory of plane or pointed wings of low aspect ratio. It is shown that all the parameters depend on the Mach Number, and that the theory can be applied to cases of small elastic deformations. Comparison with the Lange and Behrbohm mathematically exact calculations on triangular wings for small aspect ratios and with the Prandtl-Glauert law for standard aspect ratios shows good agreement.

APPLICATION OF DRAG-REDUCTION METHODS TO SUPERSONIC BIPLANES. Appendix---ALTERNATIVE PROOF OF NON-INTERFERENCE OF CERTAIN SYMMETRIC AND ANTISYMMETRIC LIFT AND VOLUME DISTRIBUTIONS. M. E. Graham. Douglas Rep. SM-19258, Sept., 1955. 74 pp. 14 refs. Theoretical analysis, taking into consideration the singularity distributions along the axis

where the fuselage is to be located and in the two planes where the wings are to be situated, rather than the actual wing and fuselage shapes. The analysis is based on the Hayes method and applies the linear theory.

APPROXIMATE INDICIAL LIFT FUNCTIONS FOR SEVERAL WINGS OF FINITE SPAN IN INCOMPRESSIBLE FLOW AS OBTAINED FROM OSCILLATORY LIFT COEFFICIENTS. J.A. Drischler. US, NACA TN 3639, May, 1956. 26 pp. 13 refs. Calculation of the indicial lift functions for a wing undergoing a change in sinking speed in an incompressible medium from the oscillatory lift coefficients for a wing oscillating harmonically in pure translational motion. Functions are presented for delta wings having aspect ratios of 0, 2, and 4, and the local and total functions for elliptical and rectangular wings having aspect ratios of 0, 3, and 6. Results indicate that the growth of lift for delta wings is more rapid than that for elliptical and rectangular wings of the same aspect ratio; that for elliptical or rectangular wings the spanwise distributions of the lift are substantially independent of time; that the normalized unsteady-lift functions are relatively independent of plan-form shape for elliptical, rectangular, or moderately tapered wings; and that the growth of lift, for all wings investigated, is more rapid as the aspect ratio is decreased.

WIND-TUNNEL INVESTIGATION OF THE EFFECT OF CLIPPING THE TIPS OF TRIANGULAR WINGS OF DIFFERENT THICKNESS, CAMBER, AND ASPECT RATIO - TRANSONIC BUMP METHOD. H.F. Emerson. US, NACA TN 3671, June, 1956. 183 pp. Test results giving lift, drag, and pitching moment data on a series of triangular wings whose tips are clipped progressively. Four basic plan forms are tested with aspect ratios of 2.0, 2.5, 3.0 and 4.0, and taper ratios of 0.1, 0.2, 0.3, and 0.4. The NACA 63A00X profile is used with thickness-to-chord ratios of 0.02, 0.04, and 0.06. Data is obtained over a Mach Number range from 0.6 to 1.10 corresponding to a Reynolds Number range from 1.85 million to 2.9 million. Results indicate that wings with clipped tips have higher valued lift slope curves than those with pointed tips. When the taper ratio is increased from 0 to 0.1, the values of the drag-rise factor decrease. Also cambered wings have consistently lower values of drag-rise factor than plane wings. In general, the values of pitching-moment-curve slope become less negative with increasing taper ratio.

EXACT AND APPROXIMATE SOLUTIONS FOR THE SUPERSONIC DELTA WING. L. R. Fowell. J. Aero. Sci., Aug., 1956, pp. 709-720, 770. 14 refs. Results of a theoretical investigation to obtain an exact solution of the equations governing steady inviscid supersonic flow with constant stagnation enthalpy about an infinitely thin flat wing with supersonic leading edges at a finite angle of attack and zero angle of yaw -- a problem in exact cone field theory. The methods used are indicated. Analysis results in: the derivation of exact solutions for the flow over the compression surface and for that over the expansion surface in the continuous case; the determination of the boundaries of the domain of the wing apex (except the shock segment on the compression side) and the derivation of the solutions outboard of the boundaries; the establishment of a singularity in the entropy along the wing centerline; and the determination of the region of nonzero entropy gradients as well as calculation of the rotationality effect on the compression side. The solutions within the apex domain are found by relaxation processes -- that on the compression side involving an iteration procedure for the location of the curved shock portion of the domain boundary. Includes description of a method to yield a close approximation to such exact solutions by means of an adjustment of the linearized solution, based upon a matching of the linearized and the exact solutions at the boundary of the apex domain, and also of an approximate procedure of solution for the discontinuous case of the flow over the expansion surface, in which the discontinuity takes the form of a conical shock, with experimental confirmation.

AEROELASTICITY

AEROELASTIC PROBLEMS OF LOW ASPECT RATIO WINGS. V---APPLICATION OF THE STRUCTURAL AND AEROELASTIC MATRICES TO THE SOLUTION OF STEADY STATE AEROELASTIC PROBLEMS. J.E.F. Farbridge, F.A. Woodward, and G.E.A. Thomann. Aircraft Eng., June, 1956, pp. 196-198. Description of a method for obtaining stability derivatives of the elastic wing by using a system of unit loads, and a discussion of the occurence of wing divergence and control surface reversal speeds.

THE INTEGRAL EQUATIONS OF AEROELASTICITY. Appendix I - EXPERIMENTAL DETERMINATION OF INFLUENCE FUNCTIONS FOR A SWEPT WING. Appendix II - REMARKS ON THE USE OF HAMILTON'S PRINCIPLE. J.R.M. Radok. Australia, Aero. Res. Comm. Rep. ACA-56, May, 1955. 32 pp. 14 refs. Formulation of a unified theory of all aeroelastic phenomena, based on the derivation of equations of equillibrium. The analysis considers the problems of static aeroelasticity, including aileron reversal and wing divergence, and of dynamic aeroelasticity, including free and forced vibrations in vacuo, flutter and dynamic stability, and gust loads. Results indicate that the integral equation representation leads, within clearly stated assumptions, to an exact statement of the basic problems, permits the preservation of the continuous character of the underlying physical data, and offers the choice of independent variables other than deflection and twist, satisfying the special problem requirements. A close relationship is indicated between the less general matrix equations and the integral equations. Includes detailed solution of the problem of the forced motion of an aircraft subject to bending in the absence of air forces.

ON THE AERODYNAMIC INSTABILITY OF THIN PANELS. J. W. Miles. J. Aero. Sci., Aug., 1956, pp. 771-780. 16 refs. Analysis of

self-excited motion of an infinite, approximately plane, thin panel placed in compressible flow, using linearized theory. Stability boundaries are determined in a plane having as coordinates a speed parameter, mass parameter, and with the Mach Number as the family parameter of these boundaries. It is found that the stiffness required to prevent instability increases monotonically with both the mass parameter and the Mach Number, exhibiting a very steep rise with respect to Mach Number for the relatively short wave lengths representative of practical configurations, although tending to independence of the Mach Number for very large wave lengths. No analytical difficulties are found in the transonic range.

A METHOD FOR THE SOLUTION OF INSTABILITY PROBLEMS; ANALYSIS OF PENCILS OF SINGULAR HERMITIAN MATRICES. J.P.O. Silberstein. Australia, ARL Rep. SM.233, Sept., 1955. 32 pp. Description of a procedure applicable to cases in which convergence difficulties require the use of high order matrices, where matrix iteration methods are advantageous. The procedure, which is based on an extension of the theory of matrix pencils, requires the partial inversion of B, followed by a type of minimal iteration, in eigenvalue problems of the type $(A - \lambda B)x = 0$, where A and B are symmetric matrices. Results indicate that the method is most efficient when B is extremely simple; the nullmanifold of B introduces only a superficial complication; although at each step the order of the system requires an additional orthogonalization, the complete solution requires only n-q steps; and all the checks available to other iteration methods, including the important one $Up \equiv 0$, are available to this one.

SOME WIND-TUNNEL EXPERIMENTS ON SINGLE-DEGREE-OF-FREEDOM FLUTTER OF AILERONS IN THE HIGH SUBSONIC SPEED RANGE. S.A. Clevenson. US, NACA TN 3687, June, 1956. 32 pp. Results of wind-tunnel tests on three wing models with various aileron configurations. Density in the range of 0.08×10^{-2} to 0.58×10^{-2} slug per cu. ft. is found to have little effect on the initial amplitude or initial Mach Number associated with the aileron oscillations. The frequencies decrease somewhat with decrease in density and the initial Mach Number associated with buzz decreases with increasing angle of attack. Mass balancing and changes in spring stiffness have little effect and increasing the aileron mass moment of inertia lowers the oscillation frequency. The onset of buzz is delayed to a higher Mach Number by placing the aileron at the wing tip. Experimental indications are found for the buzz range limited to a range of Mach Numbers above the wing critical Mach Number.

THE BEHAVIOUR OF DAMPED LINEAR SYSTEMS IN STEADY OSCILLATION. R.E.D. Bishop. Aero. Quart., May, 1956, pp. 156-168. Description of a theoretical method which assumes hysteretic, rather than viscous damping, whereby the nature of damped vibration can be demonstrated in general terms. Includes a brief summary of the relevant features of the theory of undamped systems, and an analysis of the hysteretic damping of systems with n degrees of freedom and of systems with small damping. Results indicate that the assumption of hysteretic damping permits the development of qualitative solutions with comparative ease, simplifies the algebra to provide greater insight into the mathematical theory of damped vibration, simplifies the analysis of systems whose damping is not small, and illustrates how the introduction of damping modifies certain simple results of the standard theory for conservative systems.

A METHOD FOR DEFLECTION ANALYSIS OF THIN LOW-ASPECT-RATIO WINGS. Appendix A - INFLUENCE COEFFICIENTS FOR THE WING ATTACHED TO THE FUSELAGE. Appendix B - EXAMPLE DERIVATION OF A MATRIX EQUATION. Manuel Stein and J.L. Sanders, Jr. US, NACA TN 3640, June, 1956. 65 pp. Development of a method of obtaining the influence coefficients for low-aspect ratio wings of built-up construction. Chordwise deflections are assumed to be parabolic or linear, and the principle of minimum potential energy is used in conjunction with difference equivalents to obtain an appropriate set of equilibrium equations organized in matrix form. Symmetric and antisymmetric load support conditions are considered and influence coefficients are derived in each case. A procedure is given whereby these coefficients may be modified to obtain appropriate ones for other types of supports, including a pin-jointed mounting on a flexible fuselage.

SOME INTEGRALS RELATING TO THE VIBRATION OF A CANTILEVER BEAM AND APPROXIMATION FOR THE EFFECT OF TAPER ON OVERTONE FREQUENCIES. A.I. Martin. Aero. Quart., May, 1956, pp. 109-124. Derivation of formulas applied to the investigation of approximate numerical values of overtone frequencies of a turbine blade. The solution is used to obtain new formulas, by proceeding along the lines of the calculus of perturbation, to give second order approximations for the effects of uniform breadth and thickness tapers on the overtone frequencies. Results are presented in tabular form, with numerical values for thickness taper verified by a comparison to experimental results.

A METHOD OF SOLUTION FOR LATERAL VIBRATIONS OF A NON-UNIFORM BAR AND A CIRCULAR PLATE WITH VARIABLE THICKNESS. H. Takeyama. J. Japan Soc. Aero. Eng., May, 1956, pp. 1-7. 13 refs. In Japanese. Development of a method for solving analytically the lateral vibration equation of nonuniform bars subjected to axial forces and of circular plates with variable thickness which may be stressed axisymmetrically by rotation about their axis and heating, by transforming them into Volterra integral equations of the second type. Determination of the frequencies of the vibration of a uniform bar which is standing vertically or hanging downward and of a Fredholm integral equation of a circular plate with the fixed

type conditions along its inner and outer peripheries. The Fredholm determinant for the integral equation of a rotating bar can be expressed by the frequency equation derived from the original vibration equation.

AIRPLANE DESIGN

Air Conditioning & Pressurization

TURBOCONDITIONING SYSTEMS WITH VAPOR COMPRESSION CYCLES. J.P. Barger, W.M. Rohsenow, and K.M. Treadwell. ASME Semi-Annual Meeting, Cleveland, June 17-21, 1956, Paper 56-SA-7. 17 pp. Comparison of the relative performance and possible configurations of turboconditioning systems for cooling supersonic aircraft. Numerical values for the performance of eight different system arrangements at Mach Numbers 2, 3, and 4 are presented. The results clearly demonstrate the increasing difficulty of cooling as the speed increases, pointing to the great advantage of regeneration, especially at higher Mach Numbers. Includes flow diagrams for 24 possible systems using bled air from the engine or ram air from a separate diffuser.

Landing Gear

CORRELATION, EVALUATION, AND EXTENSION OF LINEARIZED THEORIES FOR TIRE MOTION AND WHEEL SHIMMY. R.F. Smiley. US, NACA TN 3632, June, 1956. 139 pp. 39 refs. Analysis of existing theories of linearized tire motion and wheel shimmy, and the development of a general summary theory from the kinematic relation of the von Schlippe-Dietrich type, governing the motion of elastic tires without skidding. Primary forces and moments acting on a rolling tire are used to establish the equations of motion for arbitrary rolling conditions, and a systematic procedure is developed for forming approximations to the summary theory for shimmy of more complex landing gear structures than those previously considered. Comparison of existing experimental data with the predictions of the summary theory and the systematic approximations provide a fair substantiation of more detailed approximate theories.

COMPUTERS

THE INTEGRATED USE OF ANALOG AND DIGITAL COMPUTING MACHINES FOR AIRCRAFT DYNAMIC LOAD PROBLEMS. B. Mazelsky and R. F. O'Connell. J. Aero. Sci., Aug., 1956, pp. 721-740, 780. Evaluation of the advantages and disadvantages of both the digital and analog computers, and description of an analytical method using the best features of each. Includes numerous examples of solution by the proposed procedure of several dynamic load problems for typical airframe configurations, in order to illustrate the speed and accuracy of the method.

ELECTRONICS

THE DESIGN OF HIGH-POWER TRAVELING-WAVE TUBES. M. Chodorow and E.J. Nalos. Proc. IRE, May, 1956, pp. 649-659. USAF-Navy-Army-supported experimental investigation of the problems involved in the design and operation of pulsed traveling-wave tubes operating at power levels of the order of a megawatt. Analysis includes: the procurement of a suitable slow-circuit and the development of techniques to measure the impedance and propagation properties; the design of couplers to match the circuits to conventional transmission lines over a broad-band; the attenuation for non-helix circuits; and the selection of suitable attenuating materials.

TURBULENT MIXING THEORY APPLIED TO RADIO SCATTERING. Appendix I---COMPARISON OF THE OBUKHOFF AND VILLARS-WEISSKOPF MODELS. Appendix II---COMPARISON OF THE OBUKHOFF AND BOOKER-GORDON MODELS. R.A. Silverman. J. Appl. Phys., July, 1956, pp.699-705. 19 refs. USAF-supported research applying the Obukhoff statistical theory, rather than the Gallet and Villars-Weisskopf heuristic theories, in connection with the problem of scattering due to refractive index fluctuations. Results of study indicate that, in the case of ionospheric scattering, approximate agreement with the observed scattered power is obtained if the refractive index fluctuations are attributed to electron density fluctuations produced by turbulent mixing in the lower edge of the E layer. In the case of tropospheric scattering, approximate agreement with the observed scattered power can be obtained (except during the summer months) by attributing the refractive index fluctuations to temperature fluctuations. During the summer months and at low scattering heights, humidity and its fluctuations are expected to play a prominent role. Experimental and theoretical evidence is cited in favor of perennial fractional-degree temperature fluctuations in the troposphere.

FLIGHT TESTING

QUELQUES ASPECTS DES ESSAIS DE VIBRATION AU SOL ET EN VOL. R. Mazet. France, ONERA TN 34, 1956. 17 pp. In French. Analysis of two aspects of the testing technique developed at ONERA for determining the critical velocities of prototype aircraft starting from vibration tests, and for the control in flight of the aeroelastic stability of same prototypes. Includes experimental determination of the inertia coefficient related to different natural shapes of the aircraft. The calculations gain in speed by avoiding the use of the mass estimate from predicted values. The method used is that of displacement of frequencies which assumes that the natural mode has been previously isolated from the phase resonance by an appropriate excitation. During high-speed flight testing the production of free vibrations is obtained by the explosion of impulsors located in several points of the lifting surface. Free vibration modulated in frequency is recorded on a magnetic tape.

INSTRUMENTS

Automatic Control

OPTIMALIZING CONTROL IN THE PRESENCE OF NOISE INTERFERENCE. Sedat Serdengecti.

Jet Propulsion, June, 1956, pp. 465-473. Discussion of a procedure for the detection of a modified peak-holding control system in order to determine its position in the optimum or its correct mode of operation. Procedures include direct sampling and averaging technique, using a narrow band-pass filter, direct integration technique, and filtering by the cross-correlation method. A statistical analysis is also carried out to demonstrate the efficiency of the method.

Timing Devices

TIME CORRELATOR FOR PROBLEMS IN AERODYNAMICS. G. T. Skinner. US, NACA TN 3682, June, 1956. 32 pp. Description of an instrument storing periodic samples of the signal in a box from which they are recovered after a predetermined delay time. The device makes use of the general statistical properties of the signals to be handled, which have nearly symmetrical probability distributions. A few experimentally obtained correlation functions are given in order to indicate the degree of accuracy achieved, and comparison is made between the Fourier transform function of the autocorrelation function of a random output and the power spectrum of the same function. Results indicate that the time correlator is suitable for work in turbulent flows when the effects of auxilliary equipment are taken into account, and that some modifications may be necessary for boundary-layer studies arising in acoustic radiation problems. An idea of the significant time delays can be obtained by defining a time scale from a characteristic length and the flow velocity.

MATERIALS

Metals & Alloys

EFFECT OF CRACK LENGTH AND STRESS AMPLITUDE ON GROWTH OF FATIGUE CRACKS. W. Weibull. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 65, 1956. 44 pp. Investigation of fatigue cracks using notched specimens of Unclad 24 S-T and Alclad 75 S-T done with nearly constant stress amplitudes obtained by reducing the load in proportion to the remaining area. The tests were done at small intervals during which some increase in stress amplitude was inevitable. It was found that the growth rate of fatigue cracks is strongly influenced by small variations in the mean stress amplitude of an interval. The relationship between stress amplitude and growth rate has been determined. Values of rates at given stress amplitudes, momentarily obtained in specimens in the normal way subjected to constant load amplitudes, have been compared with the present values for constant stresses. The former were somewhat lower than the latter, but the differences were too small to be considered significant.

INVESTIGATION OF PLASTIC BEHAVIOR OF BINARY ALUMINUM ALLOYS BY INTERNAL-FRICTION METHODS. R. E. Maringer, L. L. Marsh, and G. K. Manning. US, NACA TN 3681, June, 1956. 44 pp. 26 refs. Results of internal-friction tests indicating that nominal additions of 0.1, 1.0, and 5.0 weight per cent copper and magnesium to aluminum have significant effects on damping behavior. Small additions of copper raise the internal friction and lower the shear modulus above 200° C., and large additions of copper and magnesium raise the shear modulus and lower the damping. An anomalous internal-friction peak is observed at approximately 125° C. in aluminum containing 1.00% copper, supposedly resulting from the interaction of dislocations and impurity particles. The internal friction during plastic deformation is sensitive to strain rate, amount of strain, alloy content, heat treatment, temperature, and the frequency at which the measurements are made. The internal friction decreases with increasing temperature for alloys containing 0.08% copper and 0.09% magnesium but increases with increasing temperature for richer alloys.

COMPARISON OF THEORETICAL AND EXPERIMENTAL RESULTS FOR 24 S-T AND 75 S-T ALUMINIUM ALLOY COLUMNS BUCKLING IN THE ELASTIC AND INELASTIC RANGES. B. Braathen and B. R. Noton. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 66, 1956. 31 pp. 12 refs. Theoretical and experimental investigation of elastic and inelastic buckling in columns. Specimens tested include 150 aluminum columns, 17 pin-ended and 133 flat-ended. Theoretical ultimate loads are calculated on the basis of the tangent-modulus theory, the reduced-modulus theory, and the extended Southwell method, and curves of comparison prepared. Results indicate that no theory seems to give complete agreement with test results due to uncertainties concerning material properties and testing equipment. However, it is possible to estimate the buckling load of a perfect column using the extended Southwell method, but owing to uncertainties involved the simpler tangent modulus formula will give just as reliable results.

THE STRUCTURAL DAMPING OF TITANIUM AT ELEVATED TEMPERATURE. H. F. Hunter. Aero. Eng. Rev., Aug., 1956, pp. 18-21. Experimental investigation using a heated tuning fork, with results expressed in terms of the logarithmic decrement of the decaying oscillation. Includes calculation of the dynamic modulus of elasticity variation from ratios of measured frequencies. Results indicate that in the range of parameters tested, damping always increases with stress level and decreases with frequency; a frequency below 25 cycles per sec. probably exists at which damping is at a maximum and below which it decreases; short and intermediate length tuning forks display minimum damping at 500° F., while the long fork shows a relatively constant value between 80° and 500° F; the log decrement of decay varies between values of 0.0002 and 0.04 at temperatures between 80° and 1,000° F., bending stress between 1,000 and 29,000 psi, and frequencies between 87 and 600 cps; and the dynamic modulus of elasticity varies linearly with temperature, displaying approximately 75% of room temperature value at 1,000° F.

Testing

DIFFUSION CENTRALE DES RAYONS X PAR LES METAUX. Jean Blin. France, Min. de l'Air PST 311, 1956. 97 pp. 44 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Fr. 1,100. In French. Study of the diffusion of X rays by metallic crystals, in order to determine the distortions caused by the plastic deformation of crystals. Guinier results are taken into account. A Geiger-Muller counter is used and all parasitic diffusions are eliminated by placing the apparatus in a vacuum chamber. The energy of the incident beam is evaluated in order to obtain absolete diffusion coefficients for comparison between theoretical and experimental diffusion values. Includes a study of the variation of diffusion as function of the degree of the metal hammer-hardening. Metals used are copper, aluminum, and zinc, and the specimens are subjected to traction for obtaining a homogeneous deformation by maintaining the same physical conditions in the metal throughout the beam.

MATHEMATICS

ENCLOSED QUANTUM MECHANICAL SYSTEMS. T. E. Hull and R. S. Julius. U. Brit. Columbia, Dept. Math., AFOSR TN-56-209, May, 1956. 10 pp. 11 refs. Development of a method leading to a general asymptotic formula for the eigenvalue problems, which yields a simple asymptotic approximation to the eigenvalue in each particular case, once the eigenfunction of the corresponding unrestricted system is known. Approximations are derived for the three-dimensional oscillator, the hydrogen atom, and the rigid rotator. Includes a brief description of the eigenvalue problems associated with such systems and of some previous attempts to solve them.

ON A REGULAR CAUCHY PROBLEM FOR THE EULER-POISSON-DARBOUX EQUATION. E. T. Copson. Proc. Royal Soc. (London), Ser. A, June 12, 1956, pp. 560-572. Description of a method, suggesting a clue to a simple solution of the Cauchy problem, for solving the wave equation in space of any odd number of dimensions, without making use of any device for evaluating divergent intervals.

ON THE EFFICIENCY OF CERTAIN TESTS FOR 2 x 2 TABLES. J. H. MacKay. N.C. U. Inst. Statistics, MS 146 (AFOSR TN 56-192), Apr., 1956. 124 pp. 15 refs. Investigation to determine the best means of analyzing the results of an experiment, set-up as a 2 x 2 contingency table with one set of marginal totals variable. Two tests are proposed for the case of two samples of equal size from two binomial populations with the loss function symmetrical. Theories are proposed to determine the asymptotic efficiency of Fisher-Tocher tests and the approximate chi square test. Includes an asymptotic solution when the distance between alternatives and the error probabilities tends to zero.

GRAPHICAL SOLUTION OF CERTAIN NONLINEAR DIFFERENTIAL-DIFFERENCE EQUATIONS. W. J. Cunningham. J. Franklin Inst., June, 1956, pp. 621-629. 11 refs. Description of a method applicable to equations of the general form $\dot{x}(t) = f[x(t), x(t-r)]$, where r is a constant and $f[x(t), x(t-r)]$ is a single-valued function which may be nonlinear. The method, which uses a construction on the $\dot{x}(t) - x(t)$ plane, leads to a solution similar to the phase-plane solution commonly used in studying pure differential equations of the second order, yields the phase-plane curve, and locates points known in time along the curve. Solutions derived by use of the construction for two illustrative examples are compared with those derived previously by approximate analytical methods and by the use of an analog computer. All the solutions are in good agreement. The construction is also applicable to provide solutions for combinations of other numerical values where other methods are ineffective.

MISSILES

GROUND HANDLING AND LAUNCHING PROCEDURES FOR AN ALCOHOL-OXYGEN ROCKET MISSILE. T. M. Pettey, Jr. Jet Propulsion, June, 1956, pp. 474-479. Evaluation of GE equipment and procedures used in test programs involving several types of missiles having turbo-pumped feed systems. The shipped missiles are suspended inside reusable steel containers by an arrangement of rubber shear mounts. Assembly equipment includes a lifting beam and several adjustable dollies. For field transportation and erection, a modified German Meillerwagon is used. The launching stand is a tubular steel framework with a turntable for azimuth adjustment and four support arms which retract at take-off. Servicing equipment includes a movable access platform, an alcohol-supply truck, and remotely controlled oxygen, gas pressurizing, and hydrogen peroxide supply systems.

DYNAMIC BEHAVIOR DURING ACCELERATED FLIGHT WITH PARTICULAR APPLICATION TO MISSILE LAUNCHING. T. W. Oswald. J. Aero. Sci., Aug., 1956, pp. 781-791. Analysis of the dynamics of winged missiles taking into account damping and lift forces. The classical stability theory is used assuming small oscillations, and therefore the equations of motion are linear. However, since the speed is variable, the coefficients are not constant. An exact solution in terms of definite integrals of the Fresnel type is obtained. These integrals are functions of relative damping only, and are independent of frequency. Once the relative damping is determined the effects of acceleration, frequency, launching angle, thrust misalignment, and wind can be evaluated.

NUCLEAR ENERGY

AIRCRAFT DESIGN CONSIDERATIONS ASSOCIATED WITH SHIELDING FOR AIRCRAFT NUCLEAR POWER PLANTS. A. P. Fraas. IAS Natl. Summer Meeting, Los Angeles, June 18-21, 1956, Preprint 644. 7 pp. Members, $0.35; nonmember, $0.75. Discussion of the effects of radiation on organic and inorganic materials, with emphasis on human physical reactions. Includes tables of typical effects of radiation, key data for activation of representative pure materials, and re-

laxation lengths for fast neutrons and gamma rays. Ground handling and maintenance problems associated with the use of nuclear reactors in an aircraft are briefly discussed.

PHYSICS

COLLOQUE SUR LA DIFFUSION. France, Min. de l'Air NT 59, 1956. 96 pp. 37 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Fr. 1,000. In French. Contents: ÉTUDE CRITIQUE DES DÉFINITIONS FONDAMENTALES RELATIVES À LA DIFFUSION (Critical Study of Fundamental Definitions Related to Diffusion), J. Salvinien. JUSTIFICATION STATISTIQUE DE LA LOI DE LA DIFFUSION (Statistical Justification of the Law of Diffusion), J. J. Moreau. CALCUL DU COEFFICIENT DE DIFFUSION À PARTIR DE MESURES DE DIFFUSION EN RÉGIME VARIABLE (Calculation of the Coefficient of Diffusion Starting from the Measurements of Diffusion in the Variable Regime), P. Vernotte. ÉTUDE CRITIQUE DES APPLICATIONS PHYSICO-CHIMIQUES DE LA DIALYSE (Critical Study of Physico-Chemical Applications of Dialysis), R. Marignan. ÉTUDE INTERFÉROMÉTRIQUE DE LA DIFFUSION DANS LES LIQUIDES (Interferometric Study of the Diffusion in Liquids), E. Calvet and H. Patin. DÉTERMINATION DES COEFFICIENTS DE DIFFUSION À L'AIDE DES ÉLÉMENTS MARQUÉS (Determination of Coefficients of Diffusion by Means of Tracer Substances), S. Cordier. DIFFUSION AVEC PRÉCIPITATION DANS LES GELS; CAS DES PRÉCIPITATIONS PÉRIODIQUES (Diffusion with Precipitation in Gels; the Case of Periodic Precipitations), J. Salvinien. FORMATION DE LIGNES MULTIPLES PAR UN SYSTÈME PRÉCIPITANT SIMPLE LORS DE LA PRÉCIPITATION SPÉCIFIQUE PAR DOUBLE DIFFUSION EN MILIEU GÉLIFIÉ (Formation of Multiple Lines by a Simple System During Specific Precipitation by Double Diffusion in Gelatinous Media), M. Kaminski. L'ANALYSE IMMUNO-ÉLECTROPHORÉTIQUE DE MÉLANGES DE PROTÉINES (Immuno-Electrophorous Analysis of Protein Mixtures), P. Grabar.

POWER PLANTS

ZUR MECHANIK DER PHOTONEN-STRAHLANTRIEBE. E. Sänger. FPS Mitteil., Jan., 1956. 92 pp. 11 refs. R. Oldenbourg Verlag, Munich, DM 36. In German. Theoretical analysis of basic principles of jet propulsion as extended to the case of photon-jet propulsion, with discussion of chemical and nuclear rockets, ram-jets, turbojets, and propeller driven engines. Such factors as thrust, fuel consumption, operating range, exhaust velocity, aircraft acceleration, velocity, and course are taken into account.

Jet & Turbine

SOME LINEAR DYNAMICS OF TWO-SPOOL TURBOJET ENGINES. David Novik. US, NACA TN 3274, June, 1956. 35 pp. Derivation of general equations for the linear responses of inner- and outer-spool speed to change in turbine-inlet temperature and exhaust-nozzle area. Evaluation of these equations from hypothetical two-spool-engine characteristics at design speed and corroboration of the resultant equations of response developed from linearization of functional relations with experimental data. The outer-spool speed response to turbine-inlet temperature is found experimentally to be identical with the response of inner-spool speed in its approximation of a first-order lag specified by the inner-spool time constant. The analytically derived response of outer-spool speed to turbine-inlet temperature is a lead second-order lag which could result in the experimentally determined response by cancellation of terms in the response equation. With respect to changes in exhaust-nozzle area, the design-speed response of the outer-spool speed approximates a first-order lag specified by the outer-spool time constant. The inner-spool speed response approximates a second-order lag of negligible amplitude.

SELECTION OF OPTIMUM CONFIGURATIONS FOR HEAT EXCHANGER WITH ONE DOMINATING FILM RESISTANCE. E. R. G. Eckert and T. F. Irvine, Jr. US, NACA TN 3713, June, 1956. 48 pp. 14 refs. Theoretical analysis to determine which configuration requires the least energy to drive the primary fluid for a prescribed weight, volume, or frontal area. Includes calculations for the case in which the heat exchanger is inclined at an angle to the upstream direction, for several configurations. The resulting method permits the optimization of any of the parameters – power expended, weight, volume, or frontal area – with respect to the remaining three, when the heat exchanger is arranged normal to the approaching primary fluid, and the optimization of either power, weight, or volume with respect to any other of these three parameters when the heat exchanger in inclined. Results indicate that, with this arrangement, the projected frontal area of the inclined heat exchanger is equal to that of the heat exchanger requiring the minimum duct cross-sectional area when arranged normal to the primary fluid flow. Results for heat-exchanger configurations for which heat-transfer data are available are presented in the form of charts which illustrate the method of analysis and the conclussions that can be drawn.

BERECHNUNG DER OPTIMALEN LEISTUNGEN, KRAFTSTOFFVERBRÄUCHE UND WIRKUNGSGRADE VON EINKREIS-TURBOLADER-STRAHLTRIEBWERKEN AM BODEN UND IN DER HÖHE BEI FLUGGESCHWINDIGKEITEN VON 0-2000 KM/H. J. Endres. Nordrhein-Westfalen, Wirtsch. & Verkehrsmin., Forschungsbericht No. 214, 1956. 61 pp. DM 15.40. In German. Calculation of optimum performance, fuel consumption, and degree of efficiency of a turbo-compressor jet engine on the ground and in the air at velocities ranging from 0 to 2000 km/h. Results show the dependence of thrust on altitude, speed, temperature, and density at the inlet, and also indicate insufficient adaptability of the power plant to different flight conditions, speed, altitude, and load. Includes a discussion of methods for obtaining higher pressure ratios with compressors of low number of stages and of the high sensitivity of the axial compressor to the deviation from its optimal driving point.

SPANNUNGSOPTISCHE UNTERSUCHUNGEN VON TURBINENSCHAUFELFÜSSEN. K. Leist, K. Schleiermacher, and J. Weber. DVL Bericht No. 6, Mar., 1956. 56 pp. Westdeutscher Verlag, Köln & Opladen, DM 14.60. In German. Results of optical stress measurements on the base of hammer-head and Laval type turbine blades subjected to static loading. A quantitative analysis is used to determine the boundary values and the main strain regions of the blade root.

Ram-Jet & Pulse-Jet

A MECHANISM FOR HIGH-FREQUENCY OSCILLATION IN RAMJET COMBUSTORS AND AFTERBURNERS. D. E. Rogers and F. E. Marble. Jet Propulsion, June, 1956, pp. 456-462. Investigation of high frequency instability with measured stable screech limits, and amplitude and frequency of the oscillation, using photographic techniques. Theoretical analysis concludes that a mode of transverse oscillation is excited as the result of periodic transport of combustible material associated with the vortices into the hot wake of the flameholder. The vortices are generated at the flameholder lips by the fluctuating transverse velocity. When the ignition time delay lies in the proper range, the phase relationship between oscillations in transverse velocity and combustion intensity is such that the oscillation is amplified.

Rocket

GENERALIZED THEORY OF THE OPTIMUM THRUST PROGRAMMING FOR THE LEVEL FLIGHT OF A ROCKET-POWERED AIRCRAFT. Placido Cicala and Angelo Miele. Jet Propulsion, June, 1956, pp. 443-455, 473. 17 refs. Analysis of an optimum-burning program for horizontal flight. Green's theorem is used to develop a method for determining extremal paths under different types of boundary conditions. The technique of maximum range is constituted by the combination of coasting maneuvers, patterns with maximum engine output, and flights with moderate burning. A linear relationship between thrust and engine mass flow is assumed, and Hibb's results are generalized by lifting any restriction concerning the shape of the drag polar and by considering a finite maximum burning rate for the engine. Two regions of best range are dectected, one subsonic-transonic, the other supersonic. The second theory, based on the Euler-Lagrange equations, considers the general case of an arbitrary one-to-one correspondence between thrust and propellant mass flow. Also the concept of index value is presented, and shown to be an effective device in controlling the composition of the optimum path for discontinuous Eulerian solutions.

COMBUSTION CHAMBERS FOR ROCKET ENGINES. A.D. Baxter. J. Brit. Interplanetary Soc., May-June, 1956, pp. 146-163. 14 refs. Discussion of the mechanical engineering difficulties posed by the basic requirements of highly efficient conversion of the chemical energy locked up in the propellants into kinetic energy to supply useful thrust with the least possible weight and the greatest possible reliability. Includes figures to illustrate the effects of the requirements on the range or altitude which can be achieved.

ROTATING WING AIRCRAFT

A TWO-DIMENSIONAL APPROXIMATION TO THE UNSTEADY AERODYNAMICS OF ROTARY WINGS. R. G. Loewy. Cornell Aero. Lab. Rep. CAL-75, Oct., 1955. 71 pp. 23 refs. Derivation of two-dimensional oscillatory airfoil coefficients for rotary wings, taking into account the shed vorticity beneath the plane of the rotor disc, and neglecting the forward speed effects. The effect of the inflow ratio, the number of blades in the rotor, the shaping between the motions of adjacent blades, and the ratio of oscillatory to rotational frequency have been included as parameters, along with the basic reduced frequency of fixed-wing unsteady aerodynamics. Results indicate that the effects due to vorticity shed by previous blades or in previous revolutions diminish as the product of the reduced frequency and inflow ratio increases. Curves of the aerodynamic damping coefficient for flapping and pitching motions are presented. These curves indicate that such effects reduce the flap damping significantly at integer values of the ratio of oscillatory frequency to rotational frequency, and make a single-degree-of-freedom pitch instability possible at certain values of this parameter depending upon the location of the center of rotation. Application of these coefficients to classical flutter theory and other rotor problems are also discussed.

PERFORMANCE ANALYSIS OF FIXED- AND FREE-TURBINE HELICOPTER ENGINES. R. P. Krebs and W. S. Miller, Jr. US, NACA TN 3654, June, 1956. 49 pp. Theoretical investigation including: calculation of performance characteristics of the two engines, with results, in terms of the appropriate equivalent parameters, presented in the form of generalized performance charts; comparisons of off-design specific fuel consumption, altitude performance, power-speed characteristics, and response times; and calculations of flight ranges, hovering durations, rates of climb, and altitude performance of an assumed 30,000-lb. helicopter powered by each of the engines, in order to gage the importance of the differences in off-design performance of the two engines when they are used as helicopter power plants. Analysis assumes engine components representative of contemporary high-performance design, with similar components used in the fixed- and free-turbine engines wherever possible. When different components must be used, the analysis assumes that they are selected in order to have both engines with the same specific power outputs and fuel consumptions at their design points. For fixed- and free-turbine engines with identical compressors, equality of design-point performance is established when the adiabatic efficiency of the fixed turbine is set equal to the overall adiabatic efficiency of the two turbines in the free-turbine engine.

SAFETY

THE NEW NAVAL AVIATION SAFETY PROGRAM. A. L. Rasmussen. Aero. Eng. Rev., Aug., 1956, pp. 28-31. Review of the work of Naval Aviation Safety Center includes collection of failure statistics and operational data, and the publication of safety material. Accident reports are based on the failure or unsatisfactory report system which is processed by IBM machinery in conjunction with microfilms, and makes possible rapid reporting of accident data for immediate correction of unsafe conditions.

SPACE TRAVEL

TELEMETERING AND PROPAGATION PROBLEMS OF PLACING THE EARTH SATELLITE IN ITS ORBIT. D. G. Mazur. Proc. IRE, June, 1956, pp. 752-754. Includes a discussion of signal propagation over extended ranges, the diversity of requirements for the test and mission phases, and the need for reliable light-weight equipment.

TRACKING THE EARTH SATELLITE, AND DATA TRANSMISSION, BY RADIO. J. T. Mengel. Proc. IRE, June, 1956, pp. 755-760. Description of the NRL developed Minitrack system which is independent of time, weather, or seeing conditions for acquisition and tracking of the satellite by radio techniques, with a discussion of probable tracking accuracies. A sub-miniature radio transmitter will be provided within the satellite to illuminate antennas at ground tracking stations. By phase-comparison techniques, these ground stations will measure the angular position of the satellite as it passes through the antenna beam, recording its "signature" automatically without the need for initial tracking information. Analysis of this signature will provide the complete angular history of the satellite passage in the form of direction cosines and time.

A RESEARCH PROGRAM BASED ON THE OPTICAL TRACKING OF ARTIFICIAL EARTH SATELLITES. F. L. Whipple and J. A. Hynek. Proc. IRE, June, 1956, pp. 1956, pp. 760-764. Discussion of the problems involved in early acquisition tracking, frequent orbit calculations, ephemeris predictions for the precise photographic tracking, the establishment and operation of 12 to 15 precision photographic stations over the earth, operation of a communication net, and both current and final analysis of the positional data for obtaining more precise geophysical results. The results include density determination in the high atmosphere, geodetic system calibrations over the earth, the shape of the geoid, isostasy investigations, and other geodetic studies.

STRUCTURES

Beams & Columns

BUCKLING OF COLUMNS IN THE PRESENCE OF CREEP. S. A. Patel. Aero. Quart., May, 1956, pp. 125-134. Application of the Hoff theory of creep buckling which takes into account the instantaneous elastic and plastic deformations and the transient and secondary creep phenomena. Derivation of a general solution for integral values of the exponents appearing in the creep law. Use of this solution for the calculation of the time required for a column to collapse after load application.

Plates

BUCKLING OF SIMPLY SUPPORTED PLATES TAPERED IN PLANFORM. B. Klein. J. Appl. Mech., June, 1956, pp. 207-213. Derivation of design curves for determining the elastic buckling loads of simply supported flat plates of isosceles trapezoidal planform, loaded in compression along the parallel edges. Shear loads are assumed to act along the sloping edges, so that any ratio of axial loads may act along the parallel edges of the given plate. Solution uses the method of collocation in which the first step makes an assumption of a deflected shape as the buckling configuration. The necessary derivatives of the chosen functions are then calculated, and evaluated numerically at as many points as needed to determine the unknown generalized coefficients appearing in the functions. The results are substituted into the governing differential equations for buckling. The eigenvalue matrix form defining the buckling load is obtained directly from the original set of equations as defined.

BIEGUNG DÜNNER PLATTEN UND VARIATIONSSÄTZE BEI EINEM NICHTLINEAREN ELASTIZITÄTSGESETZ. K. Özden. Ing.-Arch., No. 3, 1956, pp. 133-147. In German. Study of the problem of bending of thin plates, with a development of three methods for the solution of basic equations of the theory of elasticity for small distortions. Results show that the first method, which leads to a series expansion of the solution, gives fairly accurate theoretical values; and that the applicability of these theories is not limited to the problem of plates, but to cases where the solution of the elasticity problem is known for Hooke's law. The Ritz and Galerkin theories are taken into account.

SOLUTION OF THE PROBLEM OF THE CANTILEVER SQUARE PLATE BY THE USE OF INFLUENCE COEFFICIENTS AND A HIGH SPEED DIGITAL COMPUTER. D. Williams and P. C. Birchall. Gt. Brit., RAE TN Struc. 178 (M.S.25), Mar., 1956. 6 pp. Solution for stresses and deflections of a square plate of constant thickness, fixed along one edge and subjected to transverse loads, using influence coefficients in conjunction with a digital computer. Method involves assigning deflections to each station to produce an arbitrary contour. This facilitates the determination of the vertical reactions that must be applied to each station in order to hold the plates to the chosen contour. The system of loads for a given contour can be obtained and expressed in terms of a set of simultaneous equations which give the reaction at a particular station in terms of its own displacements and those at other stations. By inverting the corresponding matrix, the digital computer converts the equations to give the deflection for the reactions or applied loads.

Testing

TECHNIQUES AND PROBLEMS IN TESTING STRUCTURES AT ELEVATED TEMPERATURES. L.H. Abraham. IAS Natl. Summer Meeting, Los Angeles, June 18-21, 1956, Preprint 640. 7 pp. Members, $0.35; nonmembers, $0.75. Discussion of testing methods and loading techniques for high temperature testing of materials. Methods for heating specimens include: hot gases, electric blankets, radio frequency induction heating, electrical resistance heating, solar radiation, hot body radiation, wind tunnel testing, and free flight. Except for free flight even the best of these methods can only produce a heat flux similar to a vehicle traveling at M = 8 or M = 9 at low altitudes. Load simulation by ordinary hydraulic methods is adequate for the simulation of the time-loading cycle which is encountered by a missile in flight.

Thermal Stress

THEORY AND EXPERIMENT IN THE SOLUTION OF STRUCTURAL PROBLEMS OF SUPERSONIC AIRCRAFT. I---AERODYNAMIC HEATING AND ITS EFFECTS. N.J. Hoff, M. Bloom, F.V. Pohle, H. Oliver, I. Mirsky, W. I. Berks, and A. Chwick. II---THE EFFECT OF RAPID CREEP. N.H. Hoff. III---THEORY AND PRACTICE OF INDUCTION HEATING. W.R. MacLean and S. Lederman. USAF WADC TR 55-291, Mar., 1956. 346 pp. I---Analysis of aerodynamic heating showing the effect of the boundary layer of the supersonic airflow on aircraft surface, the heat transfer from the surface to the interior of a structure, and the rise of thermal stresses in various elements of the structure due to nonuniform temperatures. Includes a review of recent work in forced-convection heat transfer, and test results on two different model wings giving transient phenomena and steady-state effects. Also includes bibliography on thermal elasticity. II---Theoretical investigation of the effect of creep deformation on stress distribution and stability. Results indicate that in both compression and tension, bars subject to creep have only a finite lifetime, and therefore must be designed for a finite time of application. III---Discussion of induction heaters for thermodynamic tests. Methods suitable for the use of closed coils surrounding the test specimen are discussed, and the heating units used at PIBAL are described in detail. The theory of the so-called thermostable work circuit is developed. This system maintains the efficiency of the heating process approximately constant despite the changes in the temperature of the specimen. Experiments are described in which the theory of the thermostable work is verified.

PHOTO-THERMOELASTICITY: AN EXPLORATORY STUDY. G. Gerard and A. C. Gilbert. NYU Coll. Eng. TR SM 56-11 (AFOSR TN 56-237), May, 1956. 38 pp. Investigation of optical and physical properties of a photoelastic model material Paraplex P-43 over the temperature range from room temperature to -40°F. Presented are techniques and equipment for obtaining the modulus of elasticity, the material fringe value, and the thermal expansion coefficient as a function of temperature. Further investigations are conducted into the plane stress problems of a disc contracting upon an elastic inclusion, and the transient thermal stress produced by a temperature differential suddenly applied to the upper edge of the beam. The data are correlated with theory using the material properties obtained in the calibration phase. Also includes photographic results of an exploratory investigation of the thermal shock phenomenon produced by the sudden application of a temperature differential upon plastic beams of various length-depth ratios.

PANELS UNDER THERMAL STRESS; THE BEHAVIOUR OF A PANEL RESTRAINED AGAINST EXPANSION IN ONE DIRECTION AND LOADED IN THE OTHER DIRECTION WHEN SUBJECTED TO KINETIC HEATING. E.W. Parkes. Aircraft Eng., June, 1956, pp. 180-186. Theoretical analysis taking into consideration the particular problems of a panel constrained in one direction and heated, a panel loaded in two directions, and a panel constrained in one direction, loaded in the other, and heated. Includes numerical examples to illustrate: the determination of permissible temperature rise and its effect on the central deflection of a panel constrained in one direction; the calculation of safe load on a given panel for a given temperature rise and of a suitable panel thickness for a given temperature rise and load; and the plotting of a load temperature envelope for a given panel. Results for the panel constrained in one direction, loaded in the other, and heated, indicate that, although the load-bearing capacity of the panel prior to buckling is often small owing to low resistance of the panel to even temperature changes, advantage can be taken of the post-bucking properties to permit the support of considerably larger loads, and that the small ripple necessary to sustain the greater loads may be aerodynamically acceptable.

AN ENGINEERING APPROACH TO SOME STRUCTURAL PROBLEMS ARISING FROM KINETIC HEATING. E.H. Bateman. J. RAeS, June, 1956, pp. 402-407. 10 refs. Consideration of problems in supersonic aircraft design covering the nature and intensity of heat loading, thermal properties of structural materials, comparison of heat transfer by different modes, thermal insulation, transient effects of heat transfer, and steady flow through a thin skin.

Wings

MEASURED STRAINS IN A SWEPT TAPERED TUBE. I. J.E. Wheeler. Australia, ARL Rep. SM. 237, Jan., 1956. 36 pp. Experimental and theoretical investigation to determine the stresses on a swept, tapered tube, representing a two-spar swept-wing torsion box with ribs parallel to the line-of-flight. The stress distribution for an outboard section is obtained from strain measurements, and the results are compared with stresses computed by the Wittrick theory and with the simple theories of bending and torsion. Results indicate that the two sets of computed stresses are in reasonable agreement with the tests.

THERMODYNAMICS

Combustion

ÉTUDE EXPÉRIMENTALE DE LA COMBUSTION DE GOUTTES DE MONERGOL. M. Barrère and H. Moutet. La Recherche Aéronautique, Mar. -Apr., 1956, pp. 31-38. In French. The square of the droplet diameter varies linearly with time during the combustion process, whereby the constant of the monergol combustion and the constant of the test conditions can be determined independently of the droplet diameter. The constant varies with the nature and the temperature of the surrounding media. In the neutral atmosphere the combustion is not possible when the temperature becomes lower than a critical value. An oxidizing atmosphere, particularly air, increases the combustion constant, even during poor mixing.

CARBON FORMATION FROM ACETYLENE IN THE SHOCK TUBE. E. N. Bennett. CIT Guggenheim Jet Propulsion Cen., AF 18 (603) TR 2, June, 1956. 85 pp. 12 refs. Theoretical and experimental investigation to determine analytically the state of acetylene behind incident and reflected shocks for a wide range of shock strengths and for various excitation models of the internal degrees of freedom, and to establish experimentally the shock strengths required to initiate decomposition of acetylene at various pressures Analysis includes estimates of the minimum times spent by the gas in a uniform state at elevated temperatures behind reflected shocks. Tests include temperature estimates, shock velocity measurements, and spectroscopic studies to determine the light emitted in a narrow wave length during chemical decomposition behind reflected shocks. Analysis assumes a simple mechanism - the formation of solid carbon and hydrogen - for the thermal decomposition. Results of temperature estimates and shock velocity measurements indicate that the effective specific heat ratio approaches the equilibrium value, while those of the spectroscopic studies show that the intensity distribution follows the black-body emission law, suggesting that future investigations use a two-color method to measure the temperature as a function of time behind carbon-forming shocks.

Heat Transfer

A RAPID ANALYTICAL METHOD FOR CALCULATING THE EARLY TRANSIENT TEMPERATURE IN A COMPOSITE SLAB. W.F. Campbell. Canada, NRC Div. Mech. Eng. Rep. MT-32, Apr., 1956. 74 pp. 19 refs. Description of a method, based on the analogy between the one-dimensional flow of heat through a slab and the flow of an electric current along a transmission line, which is capable of handling many different boundary conditions. The method is applicable to slabs made up of discrete layers, each with uniform and fixed thermal properties, and having the same temperature in all parts of the slab. Different boundary conditions, including the well-stirred fluid case, a film of pure thermal resistance, and the presence of a plane or volume heat source can be treated. Results indicate that the steady state solution of problems involving a harmonic law heat source may also be handled if all the layers are in good thermal contact.

ÉTUDE EXPERIMENTALE DE LA CONVECTION FORCÉE DE LA CHALEUR À PARTIR DE CYLINDRES À SURFACE RUGUEUSE. E. A. Brun, Giovanni Brunello, and Magdeleine Vernotte. France, Min de l'Air NT 60, 1956. 33 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, 550 Fr. In French. Experimental study of the forced heat convection on the external surface of circular cylinders. Results show that the convection coefficient depends on the relative roughness which is defined as the ratio of the height of the asperity to the diameter of the tube.

VERTICAL TAKE-OFF AIRCRAFT

LIFT ON A WING IN A PROPELLER SLIPSTREAM AS RELATED TO LOW SPEED FLIGHT. IAS Natl. Summer Meeting, Los Angeles, June 18-21, 1956, Preprint 643. 11 pp. Members, $0.35; nonmembers, $0.75. Outline of a theory for the characteristics of a wing extending through a propeller slipstream, which is based on lifting surface considerations and uses a method of analysis which is valid at all jet velocity ratios. Results of the theory, which predicts both the magnitude and the distribution of lift for any arbitrary combination of wing-slipstream geometry and all ratios of the slipstream velocity to the forward flight velocity, are in parametric form, applicable for practical design purposes and for the optimization of configurations as a function of general design parameters, such as wing loading and power loading. The method uses a vector form of the Biot Savart law which permits the use of convenient addition formulas to separate the variables, in order to represent the known perturbation flow due to the wing, in a form identical in several respects to that of the unknown perturbation flow due to the jet boundary. This similarity in form obviates further integrations and simplifies the analysis.

VTOL-STOL AIRCRAFT. II. I - A COMPARISON BETWEEN PAY-LOAD CAPABILITIES OF VTOL AND CONVENTIONAL AIRCRAFT. W.Z. Stepniewski. II - PROPELLER-LIFTED TILT-WING VTOL AIRCRAFT. Joseph Stuart 3rd. III - AN APPLICATION OF THE DUCTED PROPELLER TO A VTOL TRANSPORT AIRPLANE. J.A. O'Malley, Jr. Aero. Eng. Rev., Aug., 1956, pp. 44-55. 15 refs. I - Analysis shows the difference between the payload of a low or medium-speed VTOL transport and that of a conventional fixed-wing aircraft, which may amount to 15 or 25% of the gross weight. II - Discussion emphasizing advantages of propeller-lifted tilt-wing aircraft. These include hovering, take-off, and landing characteristics of a helicopter combined with the high performance, low vibration and noise level, superior forward flight, stability, and control characteristics of a turbine powered aircraft. III - Discussion of a ducted-fan VTOL aircraft which provides a lower noise level and a static thrust 25% higher than an unshrouded propeller.

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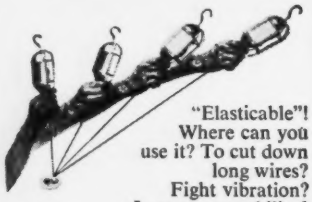

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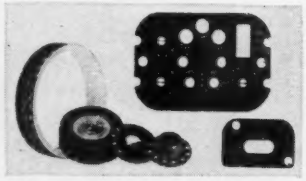

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tion Under Internal Pressure. Appendix D—**Constraining Effect of Cabin-Frames on Shell Expansion.** Appendix E—**Rear Dome of Pressure-Cabin.** D. Williams. *Gt. Brit., ARC CP 226* (Mar., 1955), 1956. 51 pp. BIS, New York. $0.90.

Landing Loads

The Analysis of Dynamic Stresses in Aircraft Structures During Landing as Nonstationary Random Processes. Y. C. Fung. *J. Appl. Mech.*, Dec., 1955, pp. 449–457. 20 refs.

Eccentric Landing with Heavy Masses at the Wing Tips. Alexander Grzedzielski. *J. Aero. Sci.*, July, 1956, pp. 653–659, 678. 10 refs. Theoretical analysis assuming a conventional aircraft whose landing gears make contact with the ground one after the other, the second contact taking place before the shock absorbing process of the first gear is completed.

Some Basic Considerations on Loads on Aircraft During Landing. J. Kloos. *Tech. et Sci. Aéronautiques*, No. 4, 1955, pp. 261–264. 18 refs. Includes analysis of such factors as the landing-load effect on the undercarriage and its attachments, wing center section, rear fuselage, and, in the case of nose-wheel aircraft, the forward parts of the front fuselage.

Operation & Performance

Analyse eines neuartigen Vorschlages zur Erleichterung der Landung von hochbelasteten Flugzeugen auf dem Deck von Flugzeugträgern. Sergio del Proposto. *ZFW*, May-June, 1956, pp. 204–212. In German. Method for facilitating the landing of highly loaded aircraft on an aircraft carrier deck through the use of blowers generating a free jet which catches the airplane.

Stopping Heavy Jets. J. E. Steiner. *Western Av.*, Feb., 1956, pp. 6–10, 29. Design considerations in terms of: the reduction in speed from which the stop is initiated; the shift of weight from wings to wheels; and the rapid, efficient, and reliable absorption of energy.

Windshields

Cabines Vitrées; Principes de Construction et Matériaux Nouveaux. M. Langlois. *Tech. et Sci. Aéronautiques*, No. 4, 1955, pp. 216–222. In French. Analysis of requirements of Perspex fittings for pressurized and climatized cabins covering mechanical resistance to temperature changes, resistance to crazing, and resistance to impact and gunfire; suitable method of fixing to the air frame; and optical qualities. Includes a description of improved joints, using laminated supports and bolts.

Electronics

IRE Standards on Audio Systems and Components: Methods of Measurement of Gain, Amplification, Loss, Attenuation, and Amplitude-Frequency-Response, 1956. E. Weber, R. F. Shea, and others. *Proc. IRE*, May, 1956, pp. 668–686. 24 refs.

On the Theory of the Acousto-Electric Effect. A. van den Beukel. *Appl. Sci. Res., Sect. B*, No. 6, 1956, pp. 459–468. Calculations of the electric field along the

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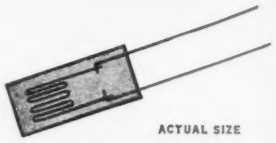

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direction of propagation to which a traveling longitudinal acoustic wave passing through an insulated solid conductor gives rise for a metal and a semiconductor at temperatures greater than the Debije temperature.

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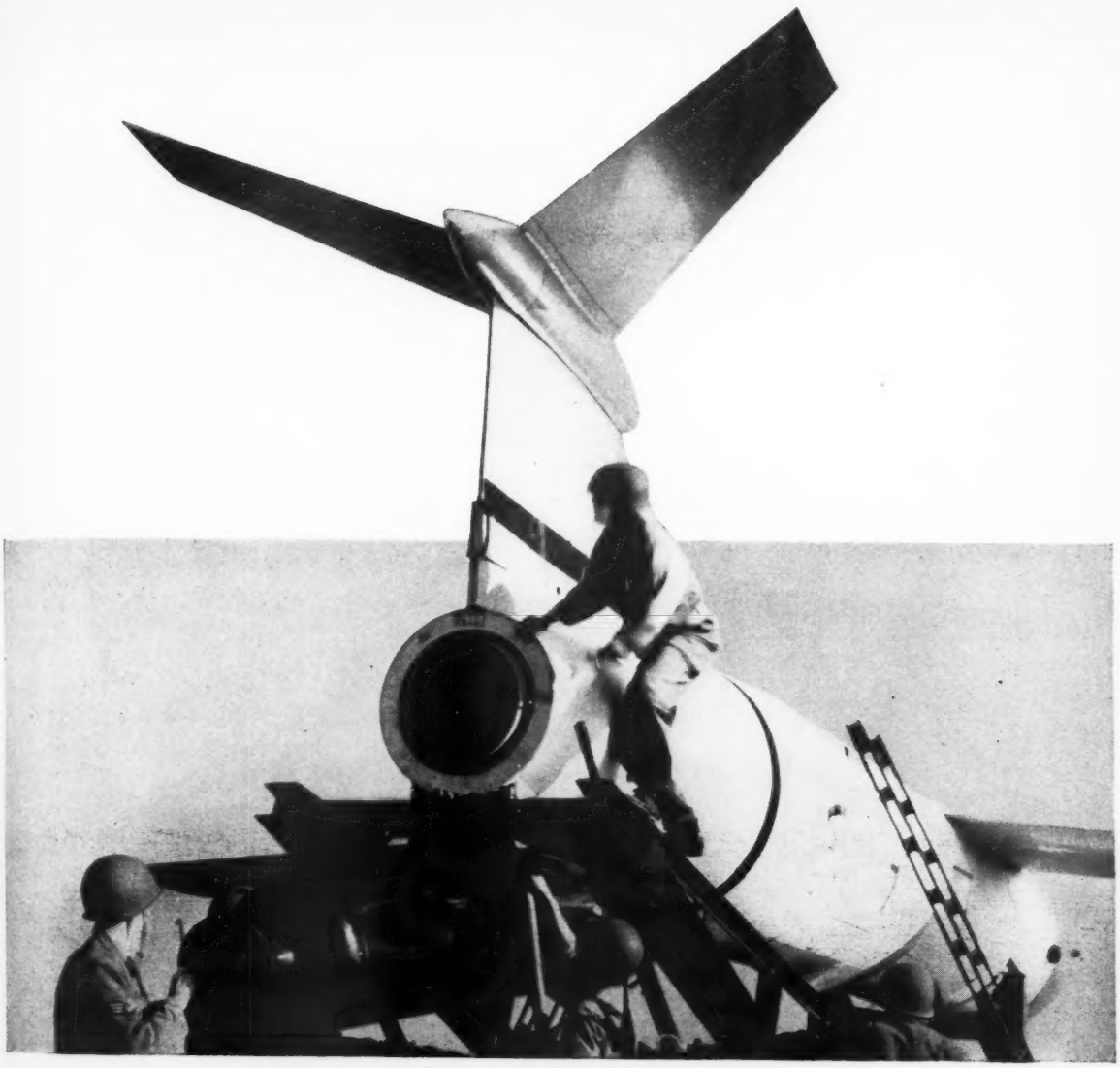

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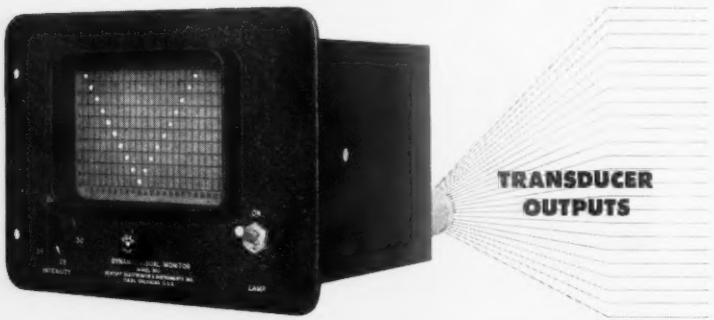

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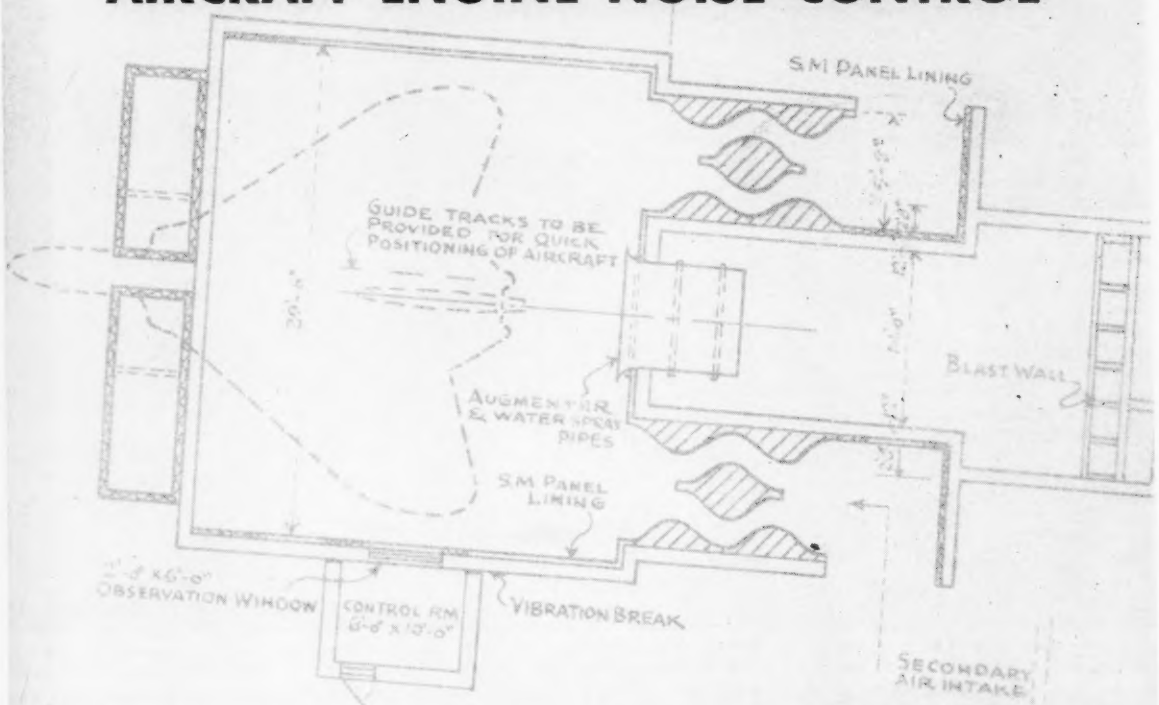

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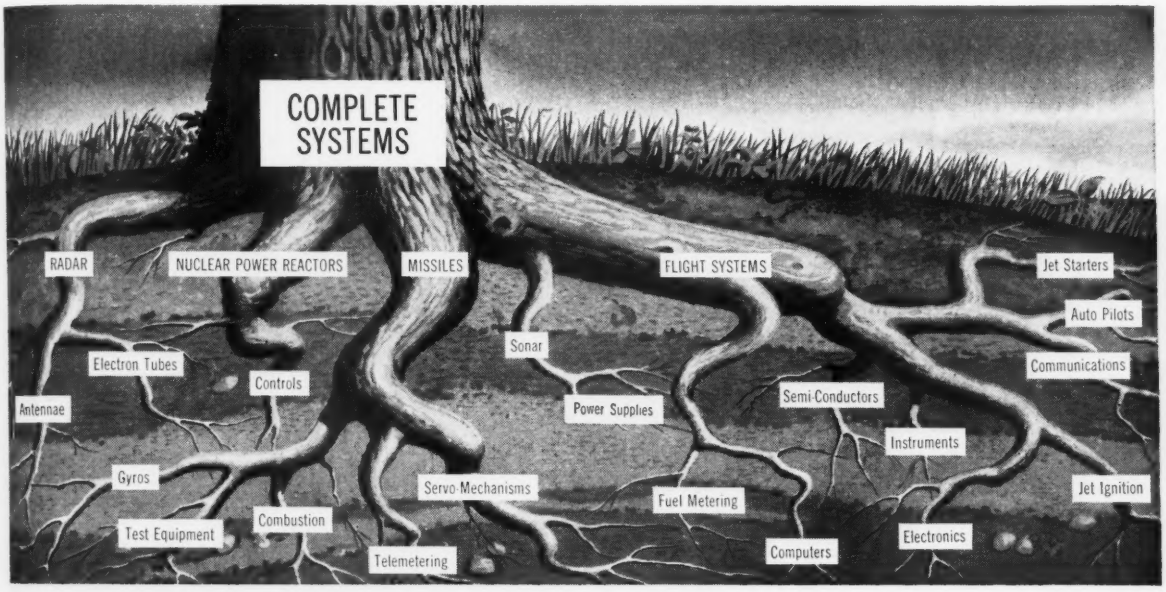

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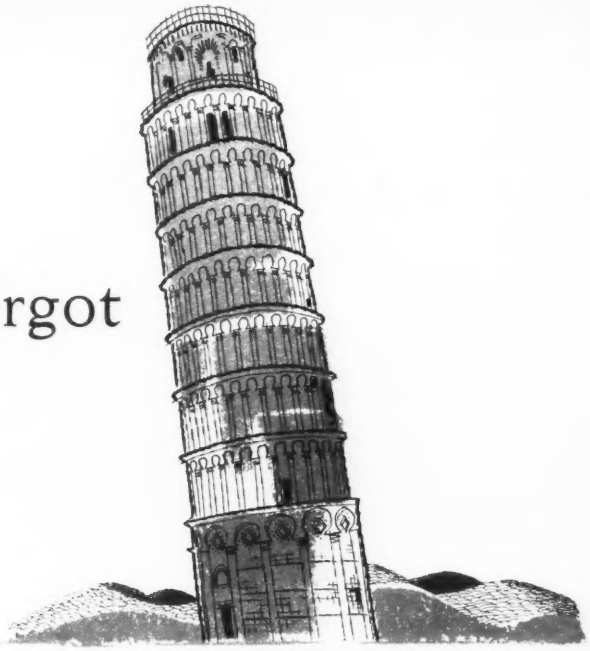

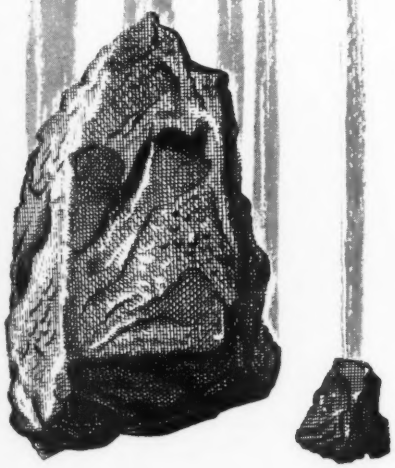

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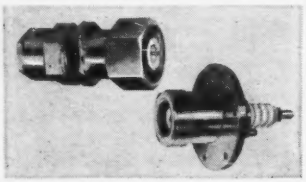

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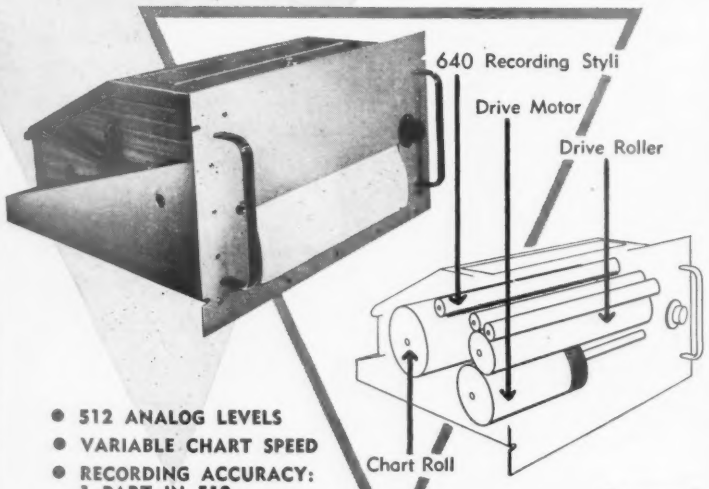

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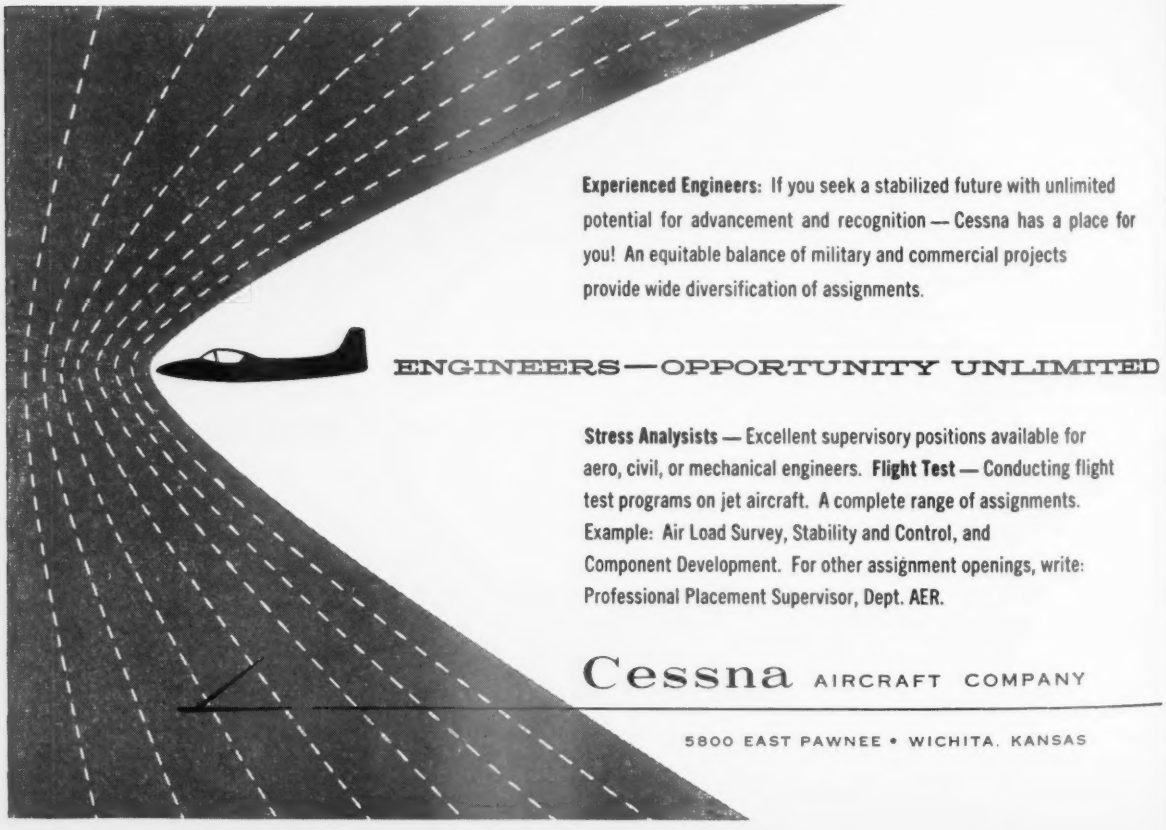
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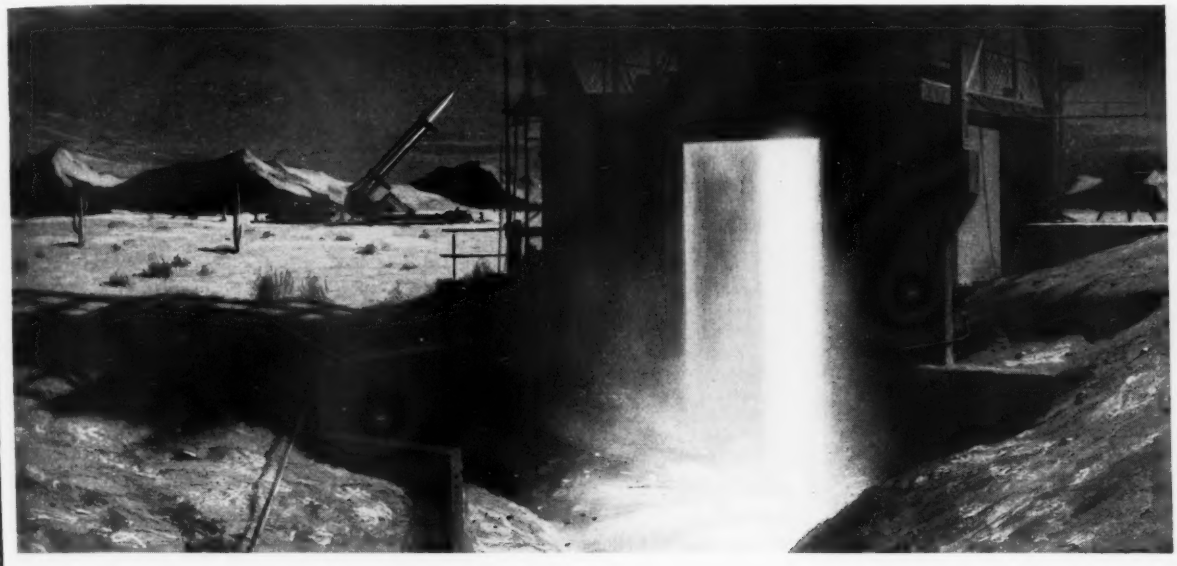

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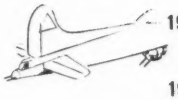

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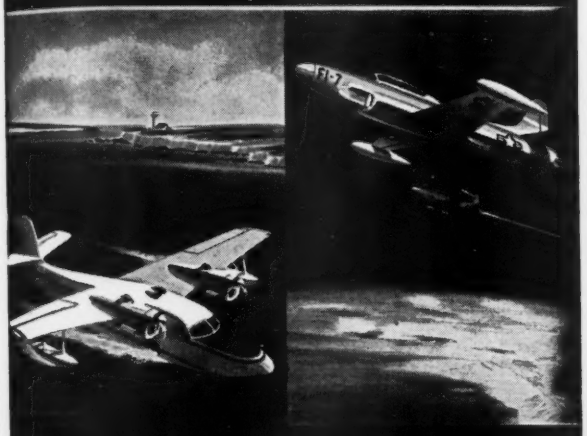

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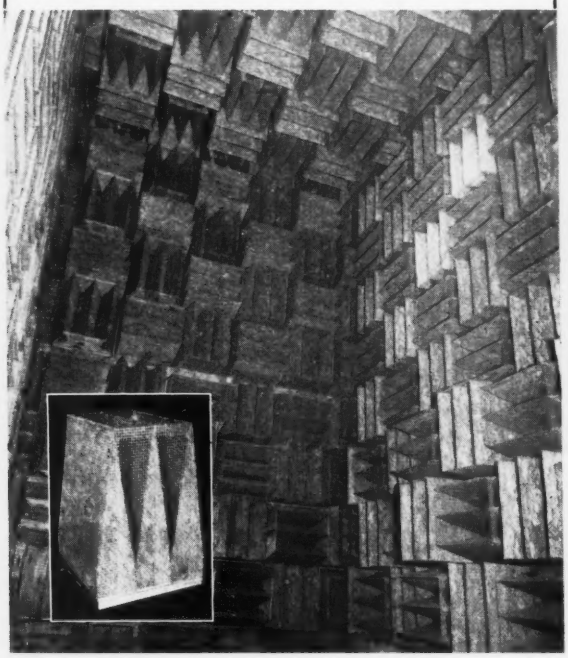

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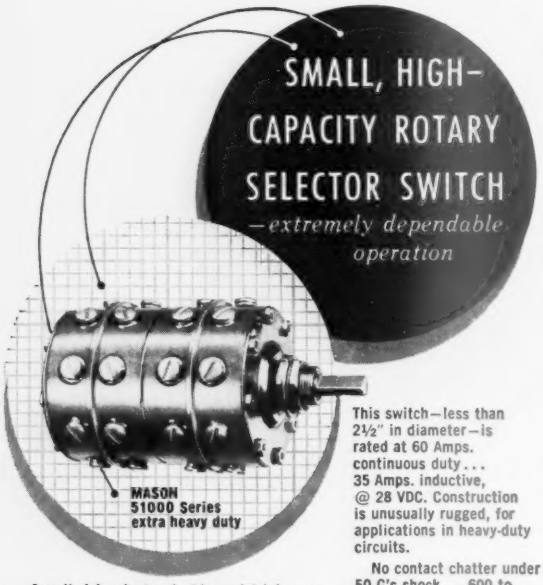

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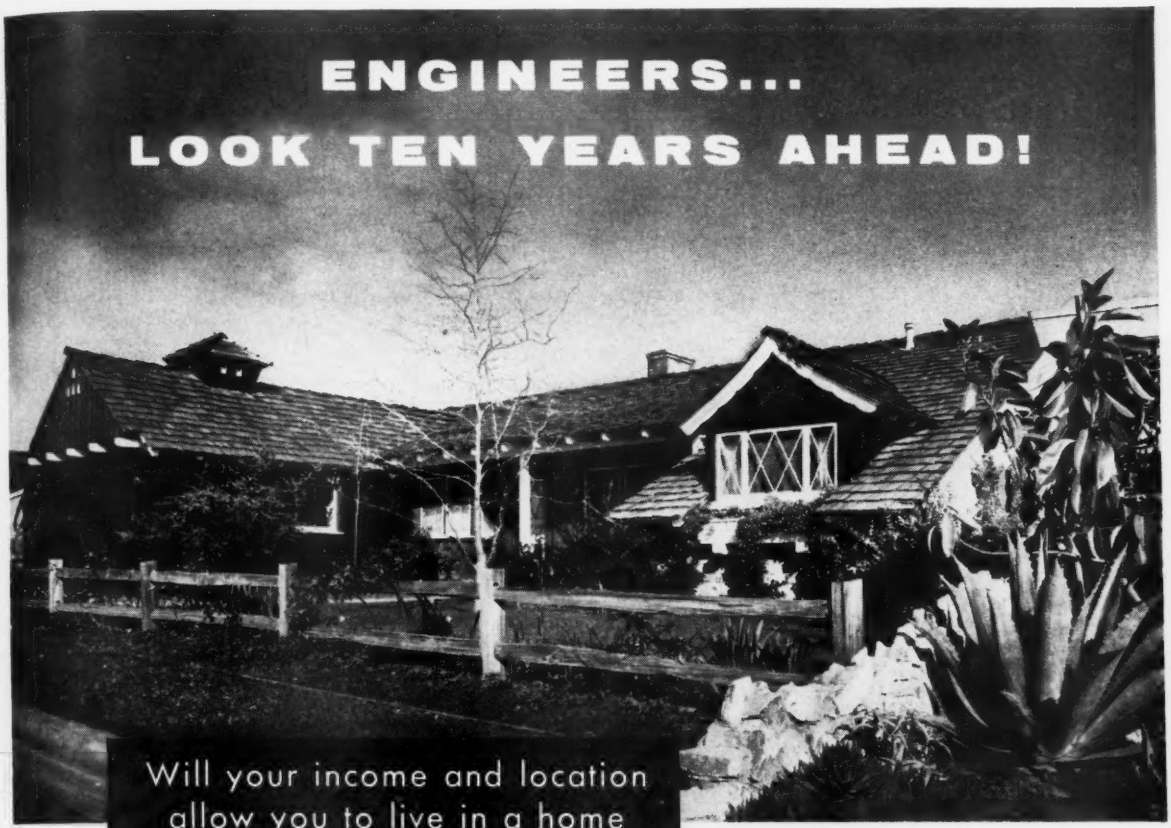

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Tunnel Aerodinamici a Forte Velocità con Azionamento ad Inerzia. Lorenzo Poggi. *ZFW*, May–June, 1956, pp. 202–204. In Italian. Discussion of the applicability of a flywheel for storing energy and driving a high-speed wind tunnel for unsteady-flow research.

Flexible-Plate Nozzle Design for Two-Dimensional Supersonic Wind Tunnels. Harold N. Riise. *CIT Jet Propulsion Lab. Rep. 20-74*, June 9, 1954. 41 pp. Development of a semianalytical method for the design of flexible-plate, potential-flow supersonic nozzle contours. The method consists of a fairly rigid control of the second and third derivatives of the nozzle displacement curve both upstream and downstream from the inflection point.

Research on the Design of Hypersonic Nozzles and Diffusers at High Stagnation Temperatures. I—Design and Construction Problems of a Hypersonic Facility and Preliminary Investigation of Liquid Film Cooling. R. Hermann, H. Leitinger, and W. L. Melnik. *U. Minn. Inst. Tech. Dept. Aero. Eng. RAL Rep. 127 (WADC TN 55-507)*, Mar., 1955. 182 pp. 33 refs.

A Simple Method for the Construction of Fixed Two Dimensional Wind Tunnel Nozzles Without Machined Contours. Seymour M. Bogdonoff. *Princeton U. Dept. Aero. Eng. Rep. 321 (OSR TN-56-167)*, Sept., 1955. 11 pp.

The Aircraft Research Association's Facilities; A Description of the New Transonic Wind Tunnel at Bedford and of Proposed Future Additions. *Aircraft Eng.*, May, 1956, pp. 140–147.

An Automatic Self-Balancing Capsule Manometer. G. F. Midwood and R. W. Hayward. (*Gt. Brit., RAE TN Aero. 2382*, 1955.) *Gt. Brit., ARC CP 231*, 1956. 22 pp. BIS New York. $0.45. Development of an apparatus to measure the pressure in supersonic wind tunnels covering a range of zero to two atmospheres absolute and calibrated to give an accuracy of 0.01 in. mercury over the range of 0.5 to 60 in. mercury absolute using a remote reading indicator for digital recording.

An Automatic Control System Operating from Small Physical Displacements. R. W. F. Gould. *Trans. Soc. Inst. Tech.*, Dec., 1955, pp. 148–151. Description of the system applied as part of the equipment of a high-speed wind tunnel to keep the absolute pressure of the air constant at any chosen value up to approximately 1.2 atmospheres.

Quelques Balances à Jauges Extensométriques des Soufflerie Françaises. P. Rebuffet. (*8th NATO AGARD Wind-Tunnel Meeting, Rome, Feb. 20–25, 1955.*) *France, ONERA NT 31*, 1956. 59 pp. In French. Analysis of fundamental concepts of dynamometric analyzers, with a review of extensometric gage balances used in French wind tunnels.

Forced Convection of Heat from Cylinders at Low Reynolds Numbers. D. C. Collis. *J. Aero. Sci.*, July, 1956, pp. 697, 698. Investigation of forced convection heat transfer of an air stream of low turbulence level, with results applicable to hot-wire anemometry.

A Study of the China-Film Technique for Flow Indication. R. J. Stalker. *Australia, ARL Rep. A.96*, Oct., 1955, 33 pp. Results of experiments on the mechanism of formation and the aerodynamic meaning of China-clay streak paterns, showing their intimate connection with a sublayer of sludge in the liquid film.

Some Results of Comparison of Model and Full Scale Spinning Tests. A. J. Marx. *8th NATO AGARD Flight-Test and Wind-Tunnel and Model-Testing Panels Joint Meeting, Rome, Feb. 20–25, 1956, Paper.* 8 pp.

Aeronautical Reviews — BOOKS

AERODYNAMICS

50 Jahre Grenzschichtforschung; Eine Festschrift in Originalbeiträgen (50 Years of Boundary-Layer Research; A Commemorative Volume of Original Contributions). Edited by H. Görtler and W. Tollmien. Braunschweig, Friedr. Vieweg & Sohn; New York, London, I. R. Maxwell & Co., Ltd., 1955. 499 pp., illus., diagrs., tables. $13.50.

This volume is issued to commemorate the fiftieth anniversary of Ludwig Prandtl's lecture, "Ueber die Flussigkeitsbewegung bei sehr kleiner Reibung (On the Motion of a Fluid with Slight Friction)," which he presented at the International Congress of Mathematicians at Heidelberg in 1904. Contrary to the impression given by the title, this is not an historical survey, for the main object of the book is to present many new facts of special interest.

Contents: 50 Jahre Grenzschichttheorie: Ihre Entwicklung und Problematik, W. Tollmien. Integral Equation Boundary Layer Problems, G. F. Carrier. Thick Laminar Boundary Layer under Sudden Lateral Perturbation, A. Mager. Ueber die in der Grenzschicht auftretende Differentialgleichung $f''' + \beta f'' + \beta(1 - f'^2) = 0$ für $\beta < 0$ bei gewissen Absauge- und Ausblasegesetzen, R. Iglisch and F. Kemnitz. Radial Jets, H. B. Squire. The Structure of Turbulence, Th. Theodorsen. Zur Berechnung des Ueberganges laminarer Grenzschichten in die Aussenströmung, A. Betz. Two Dimensional Jet Mixing of Supersonic Flow, S. I. Pai and B. B. Cary, Jr. On the Boundary Layer in Liquids, M. Z. Krzywoblocki. On the Boundary Layer in Electron Stream, M. Z. Krzywoblocki. Lignes de Courant Limites à la Paroi pour l'Aile Droite d'Envergure Infinie Dérapée, Ad. Oudart. Hypersonic Viscous Flow over an Inclined Wedge with Heat Transfer, S. I. Pai and S. F. Shen. The Stability of Boundary Layer Type Flows with Infinite Boundary Conditions, M. Lessen and J. A. Fox. The Laminar Boundary Layer on a Rotating Sphere, N. E. Hoskin. Studies of Boundary Layer Flow with a Fluid-Motion Microscope, A. Fage. Ueber die "ähnlichen" Lösungen der instationaren laminaren Grenzschichtgleichung in inkompressibler Strömung, H. Schuh. The Law of the Wall in Turbulent Shear Flow, D. Coles. Quantitative Effects of Prandtl Number and Viscosity-Temperature Index on the Compressible Laminar Boundary Layer with Pressure Gradient, J. Tinkler. Theoretical Investigation of Frictional Effects for Laminar Compressible Flow in a Tube Entry, Tau-Yi-Toong and H. Shapiro. On the Solution of the Laminar Boundary Layer Equations, I. Tani. The Calibration of the Stanton Tube as a Skin-Friction Meter, L. Trilling and R. J. Hakkinen. On Two Solutions of the Boundary-Layer Equations, B. Thwaites. Aehnlichkeitskennzahlen über die Störbewegung beim Umschlag und bei Turbulenz, W. Albring. On the Flow, Heat Transfer, and Stability of Viscous Fluids Subject to Body Forces and Heated from Below in Vertical Channels, S. Ostrach. Temperatur, Zähigkeits- und Reibungsverhältnisse in raschlaufenden Gleitlagern, B. Dizioglu. The Turbulent Boundary Layer with Variable Prandtl Number, E. R. van Driest. The Growth of the Boundary Layer Behind a Shock Wave, H. Guyford Stever, A. Witmer, and W. Herrmann. Compressible Laminar Boundary Layer with Heat Transfer and Pressure Gradient, L. Crocco and C. B. Cohen. Aehnliche Grenzschichten an Rotationskörpern, T. Geis. Dreidimensionale Instabilität der ebenen Staupunktströmung gegenüber wirbelartigen Störungen, H. Görtler. Zur Instabilitätstheorie der ebenen Staupunktströmung, G. Hämmerlin. Ueber die äussere Randbedingung bei den Grenzschichtgleichungen, H. Witting. Theoretische Untersuchung über die Wechselwirkung zwischen einem einfallenden schwachen Verdichtungsstoss und der laminaren Grenzschicht in einer Ueberschallströmung, E. A. Müller. Determination of the Heat Transfer Properties of a Turbulent Boundary Layer in the Case of Supersonic Flow when the Temperature Distribution along the Wall is Arbitrarily Assigned, C. Ferrari. The Non-Steady Aerodynamic Heating of a Plate, H. W. Emmons. A Difference Method for the Computation of the Laminar Compressible Boundary Layer, I. Flügge-Lotz. Studien zum Umschlag laminar-turbulent der freien Konvektions-Strömung an einer senkrechten Platte, E. R. G. Eckert, E. Soehngen, and P. J. Schneider. The Profile Drag of Biconvex Wing Sections at Supersonic Speeds, A. D. Young and S. Kirkby. Eine Rechenmethode für dreidimensionale laminare Grenzschichten, R. Timman and J. A. Zaat. Equilibrium Turbulent Flow in a Slightly Divergent Channel, J. R. Ruetenik and S. Corrsin. Untersuchung instabiler Grenzschichtschwingungen in einem Wasserkanal mit der Tellurmethode, F. X. Wortmann. Ueber die Grenzschicht an der Wand einer Trichters mit innerer Wirbel- und Radialströmung, K. Garbsch. The Sailplane as a Tool for Boundary Layer Research, A. Raspet.

Boundary Layer Effects in Aerodynamics; Proceedings of a Symposium Held at the National Physical Laboratory on March 31 and April 1, 1955. London, Her Majesty's Stationery Office; New York, British Information Services, 1955. 408 pp., illus., diagrs. $5.40.

Contents: (1) The Theory of Three-Dimensional Boundary Layers, R. Timman. (2) The Axisymmetric Boundary Layer on a Long Thin Cylinder, M. B. Glauert and M. J. Lighthill. (3) On the Stability of Three-Dimensional Boundary Layers, with Application to the Flow due to a Rotating Disk, N. Gregory, J. T. Stuart, and W. S. Walker. (4) Contributions on the Mechanics of Boundary Layer Transition, G. B. Schubauer and P. S. Klebanoff. (5) The Effects of Viscosity on the Type of Flow on Swept Wings, D. Küchemann. (6) Some Recent Work on Methods of Boundary Layer Control, R. C. Pankhurst. (7) The Profile Drag of Biconvex and Double Wedge Wing Sections at Supersonic Speeds, A. D. Young and S. Kirkby. (8) Interactions Between Shock Waves and Boundary Layers and Wakes, D. W. Holder and G. E. Gadd. (9) Some Effects of Shock-Induced Separation of Turbulent Boundary Layers in Transonic Flow Past Aerofoils, H. H. Pearcey.

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AEROELASTICITY

An Introduction to the Theory of Aeroelasticity. Y. C. Fung. New York, John Wiley & Sons, Inc., 1955. 490 pp., diagrs., tables. $10.50.

This work is an outgrowth of the author's classes on aeroelasticity given at the California Institute of Technology since 1948. It is intended primarily as a textbook, but it should be useful also to designers and flutter engineers, for it gives a composite picture of various aspects of aeroelastic problems. Those having a rudimentary knowledge of aerodynamics and strength of materials should have no difficulty with the material. The main body of the text is divided into two parts. Chapters 2–11 contain a survey of aeroelastic problems and their historical background, basic physical concepts, and the principles of analysis. Chapters 12–15 contain the fundamentals of oscillating airfoil theory and a brief summary of experimental results. Since this is not intended to be a handbook, attention is directed only to the fundamental principles. The physical assumptions involved in the mathematical formulation of a problem are always emphasized so that the degree of approximation relative to the real physical system can be seen. Since the author refrains from detailed discussions on such topics as flight-flutter testing, control and stability of aircraft, swept-wing analysis, stochastic theory of buffeting, and applications of digital and analog computers, he provides the reader with sufficient bibliographic guidance to existing literature on these topics.

AERONAUTICS, GENERAL

Fifth International Aeronautical Conference, Los Angeles, June 20–23, 1955. Convened by the Institute of the Aeronautical Sciences and the Royal Aeronautical Society. New York, Institute of the Aeronautical Sciences, Inc., 1956. 560 pp., illus., diagrs. $15, Members; $20, Nonmembers.

Contents: Operating Experience with Turboprop Aircraft, Peter G. Masefield. Air-Line Use of Elementary Statistical Methods in Aircraft Performance Measurement, William C. Mentzer and Frederick S. Nowlan. Design of High-Speed Aircraft, E. H. Heinemann. Design of Large Helicopters, Bartram Kelley. Stress Analysis of Multiweb Boxes, W. S. Hemp. The Interaction Between Shock Waves and Boundary Layers, D. W. Holder. Contributions to Fluid Mechanics from Shock Tube Research, I. I. Glass and G. N. Patterson. Hypersonic Flow, Lester Lees. On the Behavior of Boundary Layers at Supersonic Speeds, R. J. Monaghan. Some Results of the Princeton University Smoke Flow Visualization Program, David C. Hazen. Fatigue of Aircraft Pressure Cabins, Percy B.

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Walker. Some Influences of Equipment Installations and Systems on Aircraft Design, Charles F. Joy. Power Control Systems for Aircraft, John W. Ludwig. Jet Noise, F. B. Greatrex. Combustion for Aircraft Engines, Walter T. Olson. Low-Consumption Turbine Engines, Adrian A. Lombard. Inlet Duct-Engine Flow Compatibility, J. S. Alford. Power Plants for Supersonic Flight, Eric S. Moult.

AIR TRANSPORTATION

World Airline Record, 1955. 5th Ed. Chicago, Roadcap & Associates, 1955. 500 pp., illus., diagrs., maps, tables. $17.50.

The fourth edition of this reference volume last appeared in 1952. The rapid growth of air lines since then has seen 72 new companies added to the field, which has necessitated enlarging the present edition by 100 pages. The record now contains 269 regularly scheduled air lines in operation at the beginning of 1955. Each air line is analyzed under the following major headings: route maps, management, operations, traffic, equipment, finances, history, yearly summaries, seasonal charts, and balance sheets. An added feature is the discussion of individual air-line problems such as competition, subsidies, and other Governmental regulations.

Federal Airway Plan; Fiscal Years 1957–1961. U.S. Civil Aeronautics Administration. Washington, D.C., U.S. Department of Commerce, 1955. 82 pp., diagrs., maps, tables. $1.00.

AIRPLANES

U.S. Aviation Today, 1956. 3rd Ed. Washington, D.C., Aircraft Industries Association of America, 1956. 95 pp., illus., diagrs.

A review of aviation events of 1955. Most of the book is devoted to descriptions of current aircraft, including photographs, diagrams, and specifications.

United States Air Force and United States Army Aircraft, 1947–1956. James C. Fahey. Falls Church, Va., Ships and Aircraft, 1956. 33 pp., illus. $1.50.

This is a companion volume to the author's *U.S. Army Aircraft, 1908–1946* published in 1946. The purpose is to detail the surface characteristics of U.S. military planes. The many photos are augmented by letter-and-number model designations and other facets of military aircraft nomenclature. Specific areas covered include Models in Inventory, Markings and Insignia, Aircraft Engines, and Guided Missiles.

World Aircraft Recognition Manual. C. H. Gibbs-Smith and L. E. Bradford. London, Putnam; New York, John De Graff, 1956. 269 pp., illus., diagrs. $3.50.

This is a book for model makers, plane spotters, military personnel, and aviation hobbyists. It provides information and photographs for over 240 civilian and military aircraft (including helicopters) in use throughout the world. The aircraft have been placed into four main classes, according to their wing arrangement—delta, swept, straight, or rotary. Biplanes have been omitted. Within each division, types with similar visual characteristics—i.e., number of engines, wing positions, tail arrangement, etc.—are grouped together. This work supersedes the author's *Aircraft Recognition Manual*. It is the first in a series of annual editions, planned to be ready by February of each year.

BIBLIOGRAPHY

Bibliographical Services Throughout the World; First and Second Annual Reports, 1951–1953. L. N. Malclès. Paris, UNESCO; New York, Columbia University Press, 1955. 352 pp. $2.75.

At its sixth session (1951), the General Conference of UNESCO provided for the preparation of an annual report on the development of bibliographical services. The purpose is to present an account of these activities in various countries and to formulate suggestions for the future. The first edition of this work has combined the first two reports in one volume. The approach has

been to collect as much information as possible from the countries concerned and to identify activities, trends, or movements that are common to all countries. Material has been compiled according to geographical location. Searching is facilitated by name and subject indexes.

COMPUTERS

Computers, Their Operation and Applications. Edmund Callis Berkeley and Lawrence Wainright. New York, Reinhold Publishing Corporation, 1956. 366 pp., illus., diagrs., tables. $8.00.

This is a book for mechanical, electrical, electronic, and chemical engineers, physicists, and technicians. It presents the newest developments in both the techniques and equipment of automatic computing. All the basic elements of digital, analog, and miniature computers are explained, as well as computer reliability, advantages, limitations, and maintenance. One chapter is devoted to present and political applications of computing machines in scientific laboratories, Government, military installations, and many business markets. Other features include a convenient check list of computer characteristics; a bibliography for further research on the subject, names, and addresses of organizations from whom automatic computing equipment may be bought or rented; and a glossary of terms used in automatic computing and allied fields. The present volume is a sequel to Berkeley's *Giant Brains or Machines that Think*, published in 1949 by Wiley.

Proceedings of the Second Annual Computer Applications Symposium, October 24–25, 1955. Chicago, Armour Research Foundation, Illinois Institute of Technology, 1956. 108 pp., illus., diagrs. $3.00.

Contents: The Use of Digital Computers in Industry, R. F. Clippinger. A Dollar and Cents Approach to Electronics, John L. Marley. An Application of Computers to General Bookkeeping, W. F. Otterstrom. User Experiences and Applications of the ERA 1103, George E. Clark. Automobile Selective Underwriting and Automatic Rating on the IBM 650, C. A. Marquardt. Cutting Costs with Linear Programming, Jacob E. Bearman. Probability Forecasts in Management Decisions, Stanley Reiter. Use of the IBM 650 in Scientific Computations, A. W. Wymore. Engineering Applications of Large Scale Computers, C. B. Ludwig. High Speed Computation of Engine Performance, J. T. Horner. Pyrolysis Reactor Design Computations, H. C. Schutt and R. H. Snow. Aircraft Flight Test Data Processing, T. M. Bellan. Programming a Monte Carlo Problem, J. F. Hall and J. M. Cook.

ELECTRONICS

Aeronautical Electronics, 1956; Proceedings of the National Conference on Aeronautical Electronics, Dayton, Ohio, May 14–16, 1956. Sponsored by Institute of Radio Engineers, Dayton Section, and the Professional Group on Aeronautical and Navigational Electronics. Publications Committee, National Conference on Aeronautical Electronics, P.O. Box 621, Far Hills Branch, Dayton 9, Ohio, 1956. 663 pp., illus., diagrs., tables. $4.00.

A collection of 102 papers presented at the conference. The following various aspects of the subject are dealt with: magnetics, components, semiconductors, circuits, management, environment, electron tubes, testing and test equipment, computers, semiconductor circuits, antennas, human engineering, radio interference and R-F cables, and analysis techniques.

Transistors I. Radio Corporation of America. Princeton, N.J., RCA Laboratories, 1956. 676 pp., illus., diagrs. $4.50.

A selection of papers describing research and development work of RCA as it applies to the theory, fabrication, and application of transistors. *Transistors I* is intended to include semiconductor diodes. Although ten of the 41 papers have appeared previously in various periodicals, 31 have never been published before. The material has been arranged in six broad sections: General, Materials and Techniques, Devices, Fluctuation Noise, Test and Measurement Equipment, and Applications. Each paper contains, whenever necessary, bibliographical footnotes and a summary preceding the article. The usefulness of the volume is considerably enhanced by a concluding section containing abstracts of another 46 RCA articles which appear in various publications.

ENGINEERING

Proceedings, Second General Assembly, Engineers Joint Council, New York, January 26–27, 1956. New York, Engineers Joint Council, 1956. 68 pp., diagrs., tables. $1.00.

Contents include a discussion of the Reserve Forces Act of 1955; 8 papers on various methods for extending engineering manpower by utilizing balanced teams of engineers and engineering technicians; a view of the engineer's growth pattern as seen by the college, the employee, and the employer; and a review of the engineering aspects of the Hoover Commission reports.

FLUID FLOW

Fluid Flow in Practice. Edited by J. R. Caddell. New York, Reinhold Publishing Corporation, 1956. 119 pp., illus., diagrs. $3.00.

A collection of seven papers originally presented at the third "Experience in Industry" Symposium held in Philadelphia in May, 1955, under the auspices of the Philadelphia-Wilmington Section of the American Institute of Chemical Engineers and the Department of Chemical Engineering of the University of Pennsylvania. The material is restricted to the flow of liquids, including slurries, in pipe lines and pumps and to simple applications for gases.

Contents: (1) Review of Basic Relationships, William E. Ranz. (2) Planning New Piping Systems, Stanley A. Gertz. (3) Which Valve and Why, Otto Kneisel. (4) Which Pump and Why, Charles J. B. Mitchell. (5) Which Flow Meter and Why, Louis Gess. (6) Operation and Maintenance of Fluid Flow Equipment, Norton H. Walton. (7) Trends in Research, Alan S. Foust.

MANPOWER

Scientific Personnel Resources. National Science Foundation. Washington, D.C., U.S. Government Printing Office, 1955. 86 pp., diagrs., tables. $0.50.

The National Science Foundation Act of 1950 provides, in part, that the Foundation establish a control clearing house for information on scientific and technical personnel. This report represents the first step—a summarization of some of the data, illustrated with twelve charts and 187 tables.

Contents: (1) Introduction. (2) The Growth of Science and Technology. (3) The Supply and Utilization of Scientists and Engineers. (4) The Professional Characteristics and Employment of Scientists and Engineers. (5) The Educational System, and the Training of Scientists and Engineers. Appendix: Organizations Engaged in the Collection of Scientific Personnel Information. Bibliography.

MATERIALS

Proceedings of the Colloquium on Fatigue, Stockholm, May 25–27, 1955. Organized for the International Union of Theoretical and Applied Mechanics (IUTAM), by the Swedish National Committee for Mechanics; Held at the Royal Institute of Technology. Edited by Waloddi Weibull and Folke K. G. Odqvist. Berlin, Springer-Verlag, 1956. 434 pp., diagrs., tables. DM 46.50.

Contents: Etude Critique de la Notion de Dommage Appliquée à une Classe Etendue d'Essais de Fatigue, F. Bastenaire. Essais de Fatigue Statistiques Suivant la Méthode de Charge Progressive, F. Bastenaire, R. Cazaud, and M. Weisz. Contribution à l'Etude de la Fatigue des Matériaux avec Essais à Charge Progressive, A. Ferro and U. Rossetti. Theories Relating to Fatigue of Materials under Combinations of Stress, W. N. Findley. Effect of Simultaneous Cyclic Variation of Stress and Temperature on a High Temperature Material, A. Fransson. Physical and Statistical Aspects of Cumulative Damage, A. M. Freudenthal. Ermüdungsfestigkeit bei statistisch veränderlichen Spannungsamplituden, E. Gassner. New Statistical Methods Applied to the Analysis of Fatigue Data, F. Gatto. Ueber Verformungerscheinungen in Stählen bei der Wechselbeanspruchung, M. Hempel. The Effect of High Loads on Fatigue, R. B. Heywood. Modifications de Texture Cristalline Produites par des Efforts Alternés, R. Jacquesson. Fatigue of Steels at Constant Strain Amplitude and Elevated Temperature, A. Johansson. Une Définition Théorique de la Limite de Fatigue, A. Kammerer. Effect of Geometric Size on Notch Fatigue, P. Kuhn. Les Travaux Récents de l'Institute de Recherches Métallurgiques de Sarrebruck dans le Domaine de la Fatigue, P. Laurent. Einige Versuche über die Vorgänge in der Oberflächenschicht von Ermüngsproben, O. Lissner. Essais de Fatigue par Flexion avec Fréquences Superposées, L. Locati. Ziele der Ermüdungsforschung in der Schweiz, gezeigt am Beispiel von Dauerversuchen an Schraubenverbindungen, L. Martinaglia. Variability in Fatigue Testing: Sources and Effect of Notch Sensitivity, F. A. McClintock. Ueber den Mechanismus der Zerstörung bei der zyklischen Belastung von Metallen, I. A. Oding. Torsion and Tension Relations for Slip and Fatigue, R. E. Peterson. Einige Besonderheiten der Kontaktermüdung, A. I. Petrussewitsch. Some Observations on the Propagation of Fatigue Cracks, C. E. Phillips. Some Investigations on Cumulative Damage, F. J. Plantema. A Guide to Statistical Methods for Use in Fatigue Testing, J. T. Ransom. Die durch grosse Zug- und Druckermüdungsbelastungen hervorgebrachte mechanische Hysterese in Stählen, J. Salokangas. Der Mechanismus des Dauerbruchs metallischer Werkstoffe, C. Schaub and W. Lietdtke. A Proposed Mechanism of Fatigue Failure, F. R. Shanley. Recent Researches on Fatigue at the Mechanical Engineering Research Laboratory, East Kildride, D. G. Sopwith. Experimental Design and Methods of Analysis Used in Studying Effects of Metallurgical Variation on Fatigue, R. J. Taylor. A Contribution to the Theory of the Fatigue of Metals, G. V. Uzhik. Basic Aspects of Fatigue, W. Weibull. Ausscheidungsvorgänge in Stählen bei ruhender und wechselnder Beanspruchung, F. Wever. Bending Fatigue of Large Welded Test Pieces with Regard to Velocity of Crack Propagation, P. E. Wiene. Cumulative Damage of Fatigue, E. W. C. Wilkins. Subject Index.

Creep and Fracture of Metals at High Temperatures; Proceedings of a Symposium Held at the National Physical Laboratory, May 31–June 2, 1954. London, Her Majesty's Stationery Office; New York, British Information Services, 1956. 419 pp., illus., diagrs., tables. $5.60.

Contents: Introductory Paper, N. P. Allen. *Section I*, Deformation Processes in Simple Materials. A Discussion of Some Models of the Rate-Determining Process in Creep, N. F. Mott. Plastic Deformation of Aluminium Single Crystals at Elevated Temperatures, R. D. Johnson, A. P. Young, and A. D. Schwope. Mechanism of Grain Boundary Displacement and Its Relation to the Creep Process as a Whole, F. N. Rhines. Creep Processes, W. A. Wood. Interaction between Crystal Slip and Grain Boundary Sliding during Creep, D. McLean. Some Fundamental Experiments on High-Temperature Creep, J. E. Dorn. *Section II*, Creep Resistance of Complex Materials. Creep and Ageing Effects in Solid Solutions, A. H. Cottrell. Microstructure and Creep, J. W. Freeman and C. L. Corey. The Effect of Alloying on the Creep of Metals, L. Rotherham and C. R. Tottle. Basic Principles of a Creep Resisting Alloy, A. Constant and C. Delbart. Creep of Solid Solutions and Compounds in Metallic Systems, I. I. Kornilov. The Effect of Changing Loads during Creep, Y. N. Rabotnov. *Section III*, Theory of Fracture. An

Approach to the Problem of Intercrystalline Fracture, R. Eborall. Theory of Accelerated Creep and Rupture, C. Crussard and J. Friedel. A Theory of Brittle and Ductile Fracture, with Application to Creep Fracture, Based on the Dynamic Behaviour of Dislocations and Condensation of Vacancies, A. Kochendorfer. *Section IV*, Work on Tertiary Creep and Fracture. Observations on Third-State Creep and Fracture, C. H. M. Jenkins. Tertiary Creep of Nimonic 80A, W. Betteridge. Grain Boundary Participation in Creep Deformation and Fracture, N. J. Grant. Investigation into the Development of Intercrystalline Fractures in Various Steels under Tri-Axial Stress, W. Siegfried. Note on the Fracture under Complex Stress Creep Conditions of an 0.5%-Molybdenum Steel at 550°C and a Commercially Pure Copper at 250°C, A. E. Johnson and N. E. Frost. The Effect of a "V" Notch on the Tensile Creep Behaviour of Molybdenum-Vanadium Steel, R. W. Ridley and H. J. Tapsell.

Symposium on Basic Effects of Environment on the Strength, Scaling, and Embrittlement of Metals at High Temperatures, Cincinnati, February 2, 1955. (ASTM Special Technical Publication No. 171.) Philadelphia, American Society for Testing Materials, 1956. 114 pp., illus., diagrs., tables. $2.75.

Contents: The Role of Thin Surface Films in the Deformation of Metal Monocrystals, John J. Gilman. Structure of Oxides Formed on High-Temperature Alloys at 1500°F, John F. Radavich. Effect of Strain on the Oxidation of Nickel-Chromium Heater Alloys, Earl A. Gulbransen and Kenneth F. Andrew. An Investigation of Intergranular Oxidation in Type 310 Stainless Steel, R. E. Keith, C. A. Siebert, and M. J. Sinnot. The Properties of Oxidation-Resistant Scales Formed on Molybdenum-Base Alloys at Elevated Temperatures, M. Gleiser, W. L. Larsen, R. Speiser, and J. W. Spretnak. Oxidation at Elevated Temperatures, John F. Radavich.

Proceedings of the Second International Congress on Rheology, Oxford, July 26–31, 1953. Edited by V. G. W. Harrison. London, Butterworths Scientific Publications; New York, Academic Press, Inc., 1954. 451 pp., illus., diagrs., tables. $10.

This book consists of 55 papers read at the conference together with the material presented during discussions stemming from the papers. The aim of the conference was to cover the extended field of the "study of the deformation and flow of matter" as widely as possible. Nearly half the papers deal with the rheological properties of plastics and high polymers generally. A small section is concerned with problems of lubrication, and the remainder consider such diverse materials as clays, metals, diamonds, greases, and protoplasm. The book contains a subject index.

ASTM Standards on Light Metals and Alloys; Aluminum and Aluminum Alloys, Cast and Wrought Magnesium and Magnesium Alloys, Cast and Wrought Methods of Testing Light Metals. Philadelphia, American Society for Testing Materials, 1956. 277 pp., diagrs., tables. $3.50.

The standards include ingots, castings, bars, rods, wire, forgings, pipe and tube, sheet and plate, wrought products for electrical purposes, filler metal, electroplating, general methods of test, and the ASTM codification system for light metals and alloys.

Materials of Construction; Their Manufacture and Properties. Adelbert P. Mills. 6th Ed. Harrison W. Hayward and Lloyd F. Rader, Editors. New York, John Wiley & Sons, Inc., 1955. 650 pp., illus., diagrs., tables. $7.50.

A thoroughly revised work that is expanded 15 per cent over the fifth edition which appeared in 1939. The book is designed for the use of engineers and students and consists mainly of a detailed treatment of specific materials of construction. Industrial as well as structural applications of the materials are given. Additions include new sections on acoustical materials, mineral aggregates, and laminates and adhesives.

Index to ASTM Standards, 1955; Including List of Titles in Numeric Sequence of All ASTM Serial Designations. Philadelphia, American Society for Testing Materials, 1956. 216 pp.

The Mechanical Properties of Wrought Phosphor Bronze Alloys. G. R. Gohn, J. P. Guerard, and H. S. Freynik. (ASTM Special Technical Publication No. 183.) Philadelphia, American Society for Testing Materials, 1956. 114 pp., diagrs. $3.00.

This paper shows the effect of cold-working on the mechanical properties of a series of eight phosphor bronze alloys in two conditions in the form of cold-rolled strip with varying tin content from 0.5 to 10 per cent. Electrolytic tough pitch copper strip similarly treated is included to provide a base for evaluating the effectiveness of the tin additions.

MATHEMATICS

Introduction to the Theory of Groups of Finite Order. Robert D. Carmichael. New York, Dover Publications, Inc., 1956. 447 pp. $2.00.

A reprint of the 1937 edition. In explaining the theory of groups, fundamental theorems and their application are examined. Connections are also established between the theory of finite groups and other domains of classical and modern mathematics.

MILITARY AVIATION

The Air Force: A Panorama of the Nation's Youngest Service. Arnold Brophy. New York, Gilbert Press, Inc.; distributed by Julian Messner, Inc., 1956. 362 pp. $5.00.

A factual and interpretive account of the U.S. Air Force—its inception, development, and current status. The author, staff writer for *Newsday*, has visited air bases around the world to gather a great deal of detailed information. All the commands of the U.S. Air Force are described—their functions, the planes and equipment they use, their commanders. Background is given on the importance and problems of the aircraft industry. There is a detailed subject index.

MISSILES

Rockets and Guided Missiles. John Humphries. New York, The Macmillan Company, 1956. 229 pp., illus., tables. $6.00.

This volume is for the most part a nonmathematical introduction to rocket motors and their applications, particularly in the field of guided missiles. Both solid and liquid propellant motors are discussed, with main emphasis given to the general problems encountered in developing reliable components and units. Reference is made to specific prototype and production missiles stemming from the late war, but the book is not intended to serve as a compilation of all types of rockets and missiles. A comprehensive bibliography is included which is up to date as of September, 1955.

Contents: Introduction and History. Solid Propellant Rocket Motors. Liquid Propellants. Liquid Propellant Motors—Components. Liquid Propellant Motors—Units. Testing Motors and Liquid Propellants. Missiles—General and Guidance. Missiles—Aerodynamics. Short-Range Aerodynamics Missiles. Long-Range Ballistic Missiles. Research Missiles and Missile Testing. Aircraft Propulsion. Miscellaneous Rocket Applications. The Future—Nuclear Energy—Space Flight.

The Men Behind the Space Rockets. Heinz Gartmann. (Translated from the German: *Träumer, Forscher, Konstrukteure*, by Eustace Wareing and Michael Glenny.) New York, David McKay Company, Inc., 1956. 185 pp., illus. $3.95.

This book contains a group of biographies with a central theme. It describes the lives and work of pioneer scientists, from Ganswindt in the 1880's to von Braun of today, who have devoted themselves to the great ideal of the conquest of space.

Contents: (1) Ganswindt and the Birth of a Theory. (2) Tsiolkovski—the Pioneer Schoolmaster of Kaluga. (3) Goddard and the Development of the Rocket in America. (4) Oberth—the "Grand Old Man" of Rockets. (5) Valier and the Last of the Individualists. (6) Sänger and the Modern Epoch of Technology. (7) Zborowski and the Forcing-House of War. (8) Wernher von Braun and the Long-Range Rockets. (9) The Future of the Rocket. Index of Names.

Missile Progress Handbook. Washington, D.C., American Aviation Publications, 1956. 66 pp., illus., diagrs., tables. $2.00.

A selection of 18 articles about pilotless weapons, reproduced from the engineering-development issues (1954 and 1955) of *American Aviation* magazine. Two of the articles deal with the Soviet position in the field.

NUCLEAR ENERGY

Conference of the Academy of Sciences of the USSR on the Peaceful Uses of Atomic Energy, July 1–5, 1955. U.S. Atomic Energy Commission. In English translation by Consultants Bureau. Washington, D.C., U.S. Government Printing Office, 1956. Vol. 1, 259 pp., $1.25; Vol. 2, 197 pp., $1.00; Vol. 3, 214 pp., $1.00; Vol. 4, 193 pp., $1.00.

The proceedings of this conference were published in the original Russian in five volumes. For convenience of format, reports to the Plenary Session are included in the appropriate volumes in this translation, thus reducing the English edition to four volumes.

Contents: Vol. 1, Physical and Mathematical Sciences (23 papers). Vol. 2, Biological Science (21 papers). Vol. 3, Chemical Science (19 papers). Vol. 4, Technical Science (18 papers).

PRODUCTION

Aircraft Production Methods. Gordon B. Ashmead. Philadelphia, Chilton Company, 1956. 293 pp., illus. $7.50.

Many of the important production techniques are collected and described in this manual. The production process is followed from the blueprint stage to the inspection of the finished product. This predominantly pictorial presentation is highlighted by 300 photographs. The author at present is Technical Editor for Douglas Aircraft Company, Inc.

Contents: (1) Introduction to Aircraft Production. (2) The Master Plaster Pattern and Foundry. (3) Sheet Metal Preparation. (4) Sheet Metal Forming—The Drop Hammer, etc. (5) Sheet Metal Forming—The Draw Press, etc. (6) Sheet Metal Forming—Bending Rolls, etc. (7) Sheet Metal Forming—The Guerin Process, etc. (8) Sheet Metal Forming—The Verson-Wheelon Press. (9) Heat Treatment. (10) Surface Treatment. (11) Tooling for Production with Plastics. (12) Optical Tooling. (13) Assembly Tooling. (14) Welding. (15) Machining—The Machine Shop. (16) Machining—Duplicating, etc. (17) Machining—Spar Milling, etc. (18) Machining—Carbide Cutter Manufacture, etc. (19) Machining—Chemical Milling. (20) Exhaust Stack Line. (21) Landing Gear. (22) Plastics. (23) Inspection. (24) Summary.

Applied Automation. Edited by James R. Custer. Philadelphia, Chilton Company, 1956. 236 pp., illus., diagrs. $7.50.

This book contains a review of important automation applications in automotive and aircraft production. The text consists of 75 selected articles which have been published during the past 4 years on that subject in Automotive Industries. Over 101 specific applications of automation are covered in a wide range of operations that include machining, stamping, welding, forging, heat treating, plating, painting, inspection, testing, and assembling.

1956 Middle Atlantic Conference, Transactions. Sponsored by the Middle Atlantic Sections & Aircraft Division of the American Society for Quality Control, February 10 and 11, 1956, Washington, D.C. New York, American Society for Quality Control, 1956. 253 pp., illus., diagrs., tables. $2.50.

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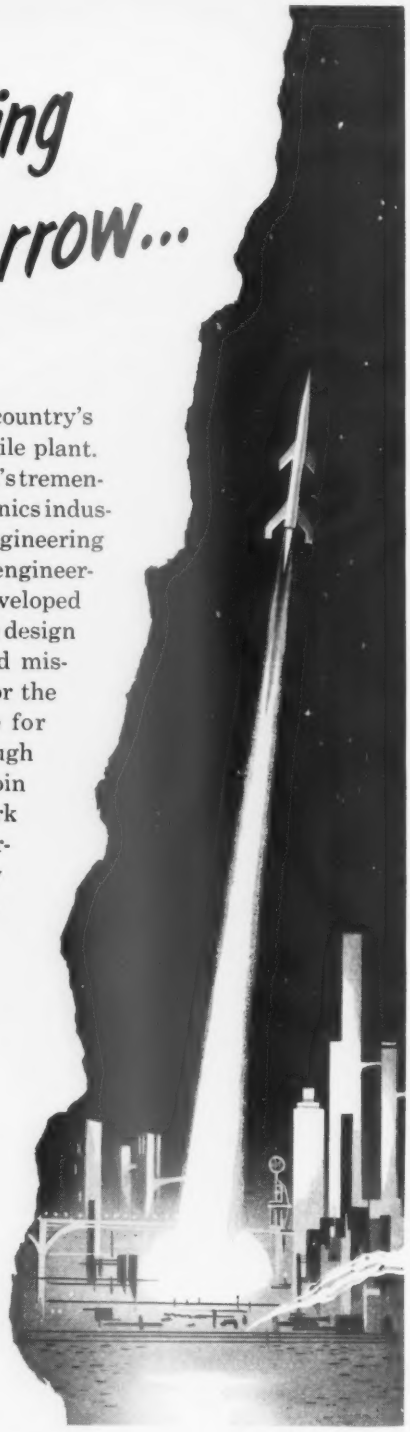

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RESEARCH

Fortieth Annual Report of the National Advisory Committee for Aeronautics, 1954; Administrative Report Including Technical Reports. Washington, D.C., U.S. Government Printing Office, 1956. 1,216 pp., illus., diagrs., tables. $8.50.

Contents: Part I, Technical Activities. The NACA—What It Is and How It Operates. Progress in Supersonic Era Requires Intense Effort. Aerodynamics. Power Plants for Aircraft. Aircraft Construction. Operating Problems. Research Publications. Part II, Committee Organization and Membership. Part III, Financial Report. Part IV, Technical Reports Nos. 1158-1209.

Industrial Research Laboratories of the United States. 10th Ed. (Publication 379.) Washington, D.C., National Academy of Sciences—National Research Council, 1956. 560 pp. $10.

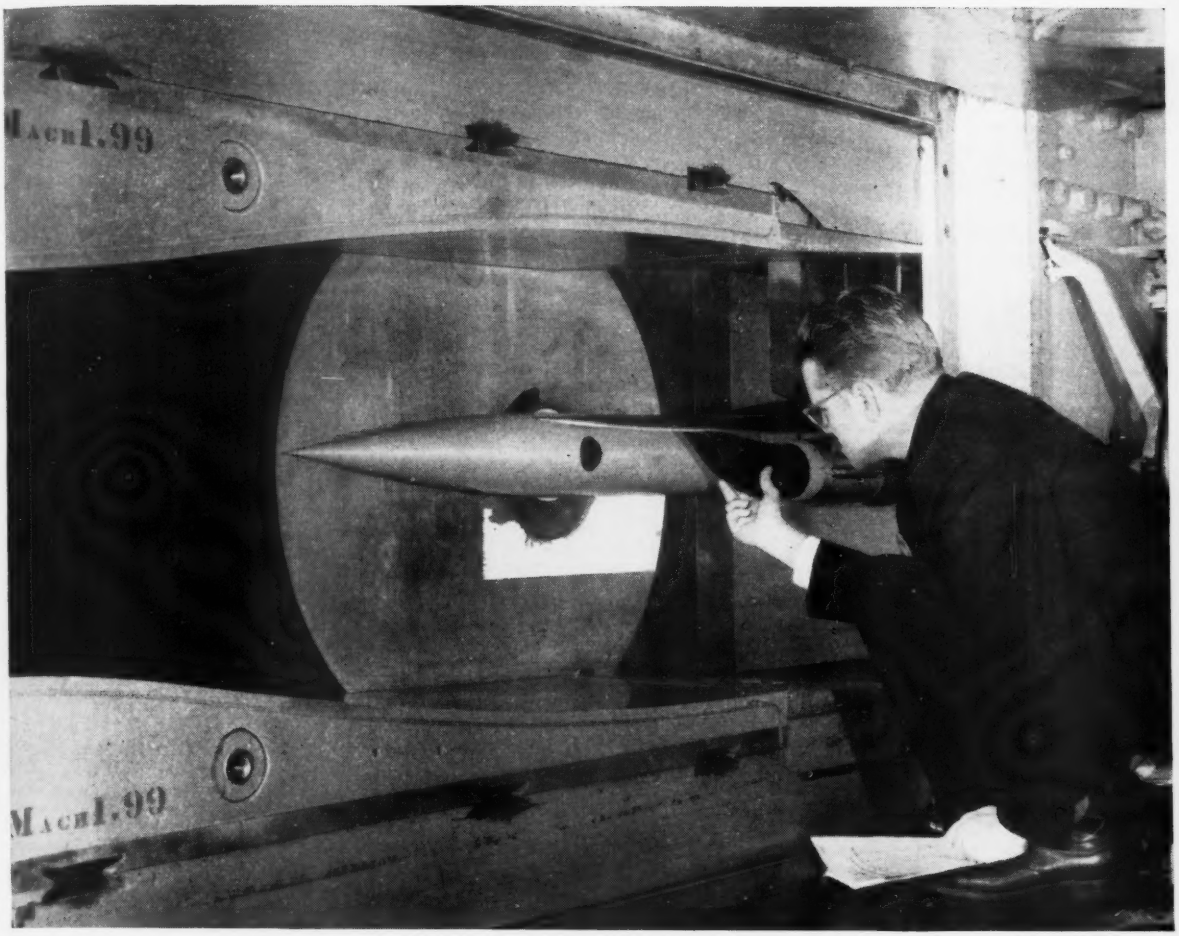
This edition contains information on 4,834 laboratories in 4,060 companies. All Government laboratories, including those operated by private contractors, and some testing laboratories have been excluded. Laboratories are listed alphabetically. For each one there is a brief résumé that includes address, president, personnel, and nature of research activities. There is a subject index and an index giving the geographical distribution of laboratories.

Aeronautical Research Council: Review for the Years 1949-1954. Ministry of Supply. London, Her Majesty's Stationery Office; New York, British Information Services, 1955. 33 pp. $0.90.

A summary of the Council's activities in aerodynamics, propulsion, and mechanics. A miscellaneous grouping is used to outline events in the fields of civil aircraft, naval aircraft, helicopters, seaplanes, gusts, and publication.

Scientific Research in British Universities, 1954-1955. Department of Scientific and Industrial Research. London, Her Majesty's Stationery Office; New York, British Information Services, 1955. 572 pp. $2.36.

The object of this volume is to provide brief notes outlining the scientific research being



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undertaken in British universities and university colleges during the 1954-1955 session. The entries are arranged in alphabetical order according to university. Within this grouping, material is alphabetically listed according to subject. Finally, within the subject groups, staff members are listed with a description of the research in which each is engaged. Alphabetical indexes of the research workers and subjects are included.

A Brief Review of Science and Technology in Western Germany. Compiled by K. H. Lauder. Department of Scientific and Industrial Research, London. Her Majesty's Stationery Office; New York, British Information Services, 1955. 103 pp. $0.72.

This is a summary of the events and accomplishments which have led to the resurgence of Western Germany in science and technology since the end of World War II. The compiler is Scientific Attaché at the British Embassy in the German Federal Republic. The major portion of the report gives synopses of the latest research undertakings and the organizations involved in the following areas: physical sciences and technology, electrical engineering and electronics, engineering, chemical sciences and technology, metals, biological and medical sciences, agriculture and forestry, and productivity in industry. Besides a list of the universities and colleges of technology of Western Berlin and Western Germany, the book contains seven appendixes: (1) List of Sponsored Research (Germany) Reports. (2) Organizations Mentioned in the Review. (3) Member Organizations of the Deutsche Forschungsgemeinschaft. (4) Institutes of the Max-Planck-Gesellschaft. (5) Member Organizations of the Deutscher Verband technischewissenschaftlicher Vereine, Düsseldorf. (6) Member Organizations of the Arbeitsgemeinschaft industrieller Forschungsvereinigungen e.V. (7) Allocation of Funds by the Forschungsgemeinschaft.

Essentials in Problem Solving. Zuce Kogan. 2nd Ed. New York, Arco Publishing Co., Inc., 1956. 119 pp., diagrs. $3.00.

The author proposes a method for problem solving which involves the formulation, adoption, and utilization of "approaches." These "approaches" are a set of general solutions to be applied to specific problems in science, technology, and human relations.

ROTATING WING AIRCRAFT

Proceedings of the Twelfth Annual National Forum, Washington, May 2-5, 1956. New York, American Helicopter Society, Inc., 1956. 100 pp., illus., diagrs., tables. $4.25.

Contents: Design Highlights of Lycoming's XT-53 Gas Turbine, Anselm Franz. Fatigue Strength of Structures Having Bolted Connections, Leonard A. Goran. The T58: A New Heritage for Helicopter Powerplants, Harold T. Hokanson. A Study in Rotor Mechanics, Bartram Kelley. Development of the XV-3 Convertiplane, Robert L. Lichten and John R. Mertens. The Rotor Acceleration Technique for Helicopter Tip Jet Engine Performance, Raymond N. Lockwood. Comments on Helicopter Design and Test Requirements, Robert E. Lynn. Experimental Investigation of Compressibility Effects on a Helicopter Rotor Having NACA 63_2-015 Airfoil Section, James P. Shivers and Paul J. Carpenter. Helicopter Instrument Flight Operations, Raymond F. Bohling. A Discussion of the Problems in the Selection and Development of Military Helicopter Pilots, William H. Coffee. Helicopter and Fixed Wing Separation Standards, Howard Higgins. Notes on Steep Instrument Approaches in a Helicopter, John P. Reeder and James B. Whitten. Factors Affecting Utilization of Utility and Light Transport Aircraft (Fixed and Rotary Wing), George Gaffney. Operating Efficiency of Verti-craft in Amphibious Operations, William MacLean. Why No More Helicopter Subsidy, James S. Ricklefs. Navigational Problems with Helicopters, Robert L. Suggs.

The following two papers, given at the Forum, were not available for inclusion in the volume at publication time: Some Aspects of Helicopter Flight Testing, W. G. Jennings; and The Use of Helicopters as Tugs, Claude T. Brown.

SPACE TRAVEL

The Exploration of Mars. Willy Ley and Wernher von Braun. New York, The Viking Press, 1956. 176 pp., illus., diagrs. $4.95.

This "guidebook to Mars" includes chapters on trajectories and orbits and on the human aspects of space travel. The text is supplemented by a Mars bibliography, tables, diagrams, historical and modern maps, and reproductions of paintings by Chesley Bonestell portraying the "voyage" and the Martian landscape.

STRUCTURES

Stresses in Aircraft and Shell Structures. Paul Kuhn. New York, McGraw-Hill Book Co., Inc., 1956. 435 pp., diagrs., tables. $14.

Correlating much of the research work in the field which has previously been available only in the form of original papers, this book is an outgrowth of work done in the Structures Research Division of the NACA. The author is Assistant Chief of this Division. The work is both a treatise for practicing engineers in the field of aircraft structures and a reference text for senior elective and graduate courses in the subject. The problems discussed include stresses due to bending of box beams (the so-called shear-lag problem in the general sense), stresses due to torsion with restrained warping, and stress around cutouts. The latter half of the book presents a large number of comparisons between tests and calculations. Wherever possible, the analysis is divided into an elementary and an advanced part. The elementary part is generally handled by automatic computers and is therefore not treated in detail. For the advanced parts, methods are presented which are simple enough not to require large-scale automatic computation.

Contents: (1) Preliminary Topics. (2) Elementary Theories. (3) Diagonal Tension. (4) Shear Lag. (5) Two-Spar Structures. (6) Four-Flange Shells under Torsion (with Restrained Warping). (7) Multistringer Single-Cell Shells under Torsion (with Restrained Warping). (8) Cutouts in Plane Panels and Box Beams. (9) Cutouts in Circular Cylinders. (10) Tests and Their Evaluation. (11) Verification of Elementary Theories. (12) Diagonal-Tension Tests. (13) Shear-Lag Tests. (14) Torsion-Box Tests. (15) Cutout Tests.

VERTICAL TAKE-OFF AIRCRAFT

Safety Through Steep Gradient Aircraft; Supplement to the 1955 Survey; Reviewing the Status and Special Problems of Vertical (VTOL) and Short (STOL) Take-Off and Landing Types of Aircraft. R. M. Woodham. New York, The Daniel & Florence Guggenheim Aviation Center of Cornell University, May, 1956. 43 pp., illus., diagrs.

Contents: (I) Introduction, T. P. Wright. (II) Status of the Art: Modified Fixed Wing Aircraft, Helicopters, Convertiplanes, VTO (Vertical Take-Off), Other Developments. (III) Hazards and Special Problems: Reliability, Metal Fatigue, Fire and Crash Hazards, Noise, Navigation Aids, Air Traffic Control, Heliports and Small Airports. (IV) Conclusions. (V) Bibliography.

VIBRATION

Fundamentals of Vibration Analysis. N. O. Myklestad. New York, McGraw-Hill Book Company, Inc., 1956. 260 pp., illus., diagrs., tables. $2.50.

This text emphasizes fundamentals and is primarily designed for a first course in vibration analysis at either the undergraduate or graduate level. Since only the classical method of analysis is used, material is developed to present a clear picture of the phenomena involved while numerical and routine methods of analysis are reduced to a minimum. Features include a new proof of the orthogonality condition, introduction of the concept of damped modes of free vibration, new treatments of vibration instruments and balancing, and numerous problems which are answered in the back of the book. The author is Head of Stress, Vibration, and Gear Group, AiResearch Manufacturing Company of Arizona.

Contents: (1) Fundamentals. (2) Undamped Vibrations of Single-Degree-of-Freedom Systems. (3) Vibrations of Single-Degree-of-Freedom Systems with Viscous Damping. (4) Systems of One Degree of Freedom with Nonviscous Damping. (5) Undamped Vibrations of Systems with More than One Degree of Freedom. (6) Application of Generalized Coordinates. (7) Damped Vibrations of Systems with More than One Degree of Freedom. (8) Tabular Methods for Finding Natural Frequencies.

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Instructors and Research Engineers—Several openings are available for men to teach and participate in research. M.S. or Ph.D. with experience in aerodynamics, dynamics, or propulsion required. Salary and rank depend upon experience. Send résumé to: E. E. Brush, Department of Aeronautical Engineering, Texas A&M College, College Station, Tex.

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